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Could one particle solve the mysteries of the universe?

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Welcome

After months of longer nights and shorter days where we've only had a small window to observe our nearest star, it's great to see the Sun grace the cover of **All About Space** this issue. This year marks Cycle 25: the point where it seems to quieten down in what we refer to as its solar minimum and where there seems to be very little in the way of activity such as sunspots, solar flares and other chaotic bubbling on its surface.

The more tempestuous time in the Sun's lifetime is referred to as its solar maximum - it's coming to the end of this phase now and, shockingly for solar physicists - but great news for life on Earth and our telecommunications - it hasn't been that earth-shattering. Our Sun has been very quiet indeed. But things could change this time around, as our best computer models and spacecraft have revealed.

We speak to the researchers behind the missions who have got up close to its searingly hot surface, hunted for trends and worked out what its future holds over the next decade or so and, crucially, how it'll affect our environment. Could we enter a mini ice age or could it all of a sudden flip and be harsher than we could have ever imagined? Find out in our special report.

Don't forget to enjoy your free posters - choose from an outstanding retro space tourism artwork for exoplanet TRAPPIST-1e or a 2019 Moon calendar!

Gemma Lavender
Editor-in-Chief

Our contributors include...

James Romero
Space science writer
James meets the researchers who have predicted just what our Sun will be doing in the next decade – harsher conditions are imminent, he finds.

Lee Cavendish
Staff writer
Lee presents the latest images of Ultima Thule from New Horizons as the mission speeds further into the Kuiper Belt. Turn to page 64.

Giles Sparrow
Space science writer
This month Giles heads to the Large Hadron Collider to find out more about a particle that could solve five big mysteries of the universe - all at once!

Stuart Atkinson
Astronomer
Make the most of the end of winter with our guide to the deep-sky, planetary and lunar targets you simply can't miss. Everything you need is on page 72.

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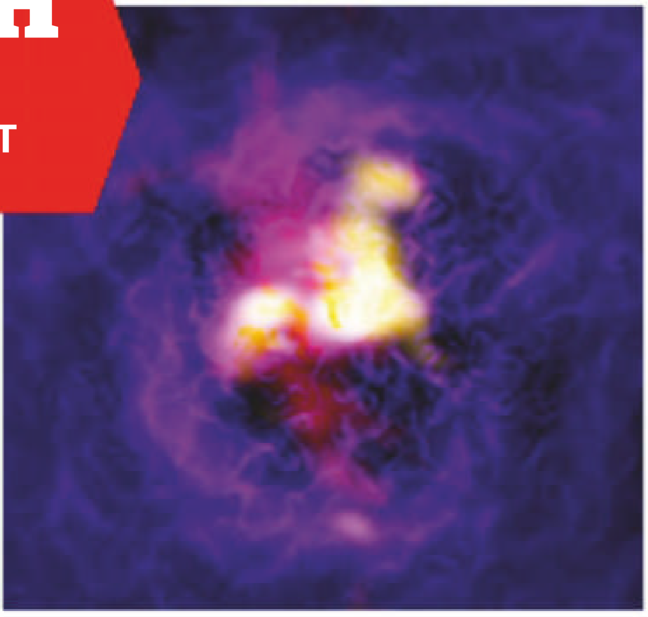

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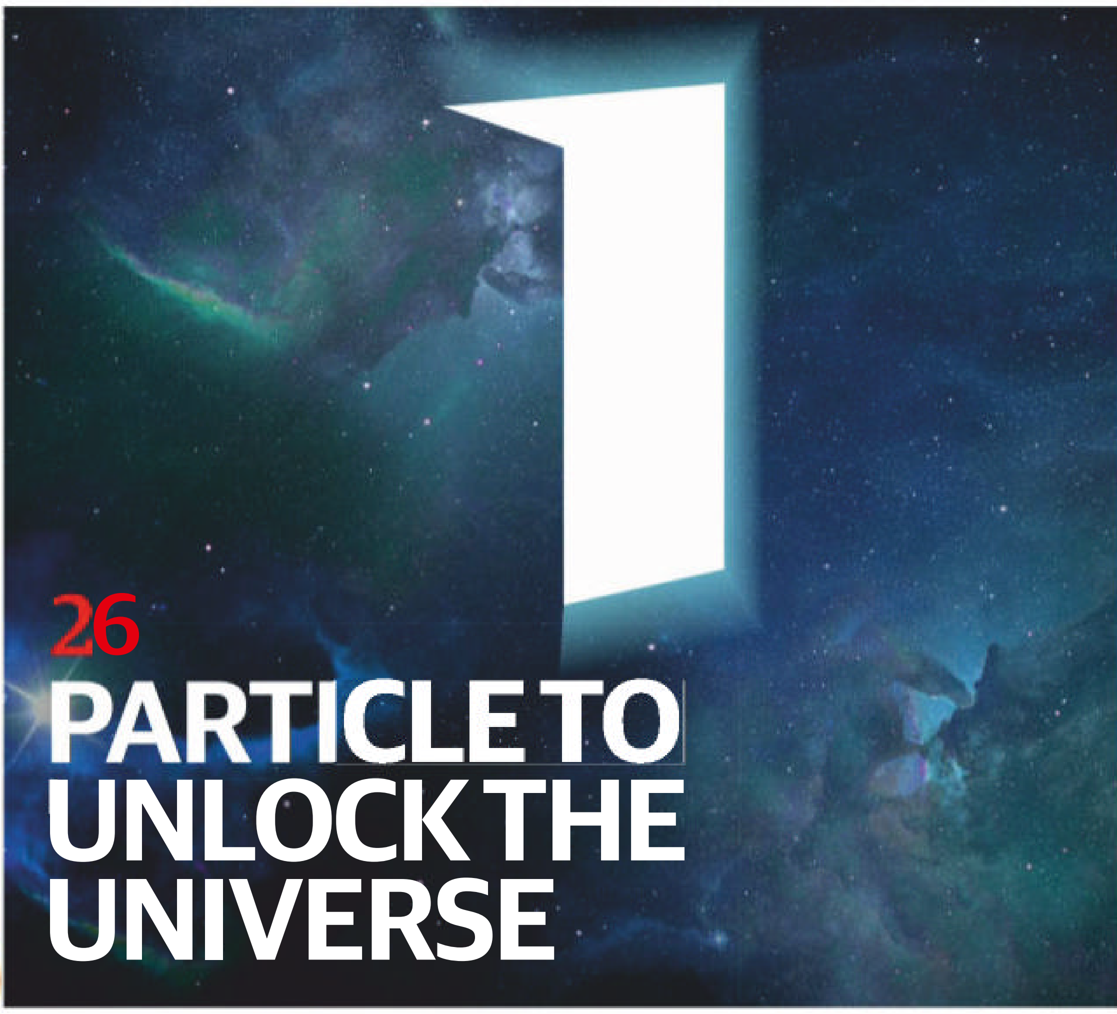

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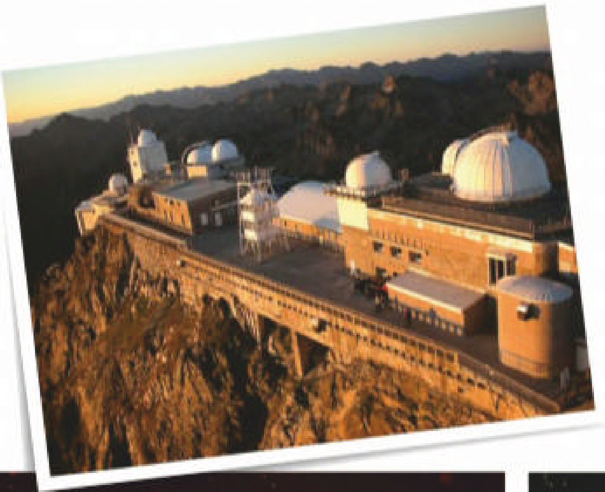

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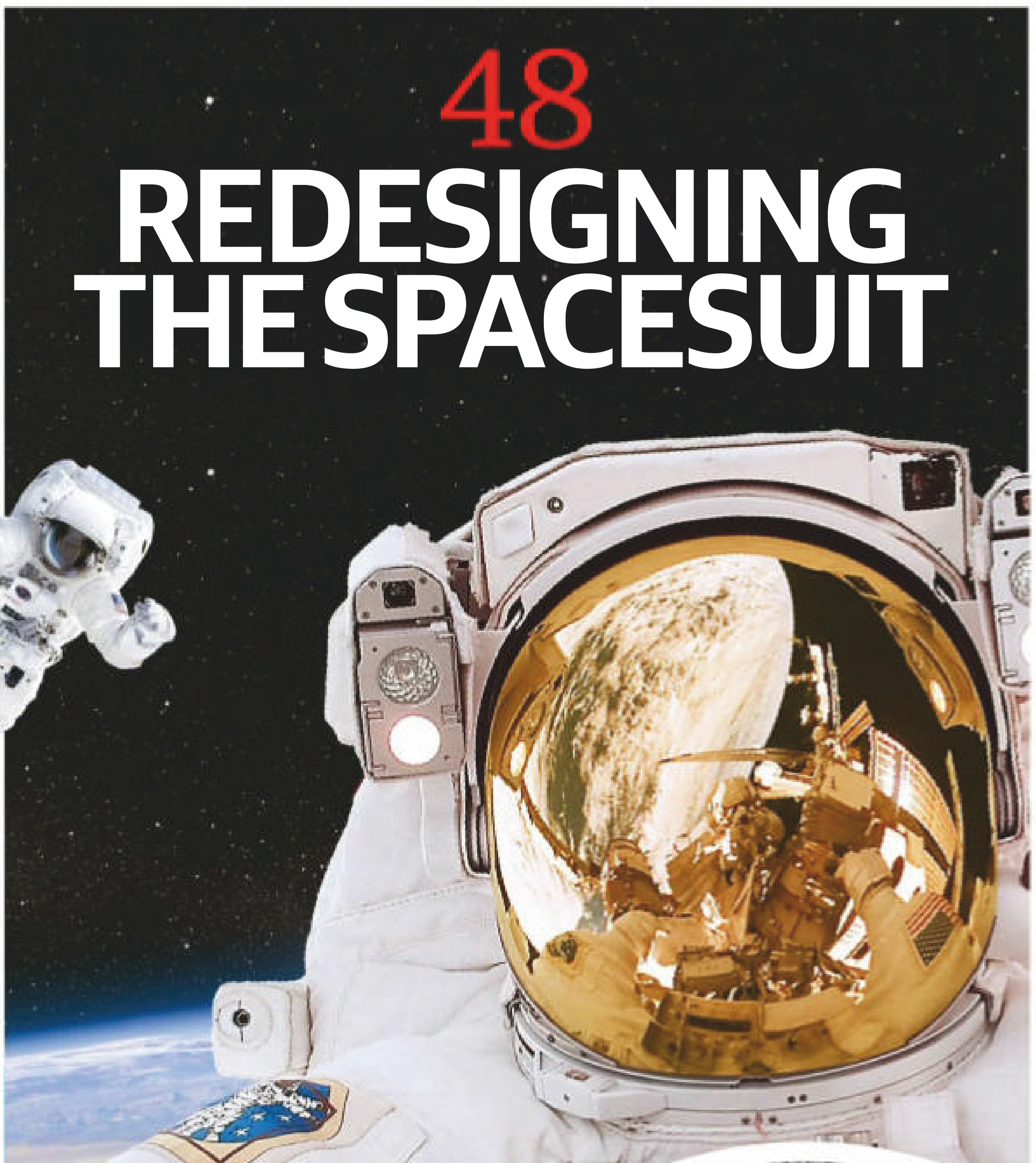

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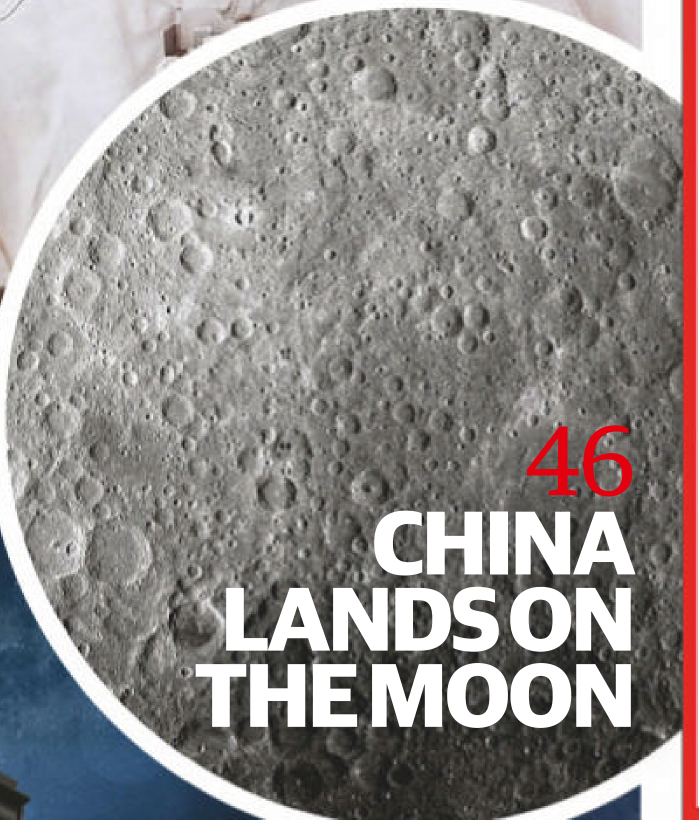

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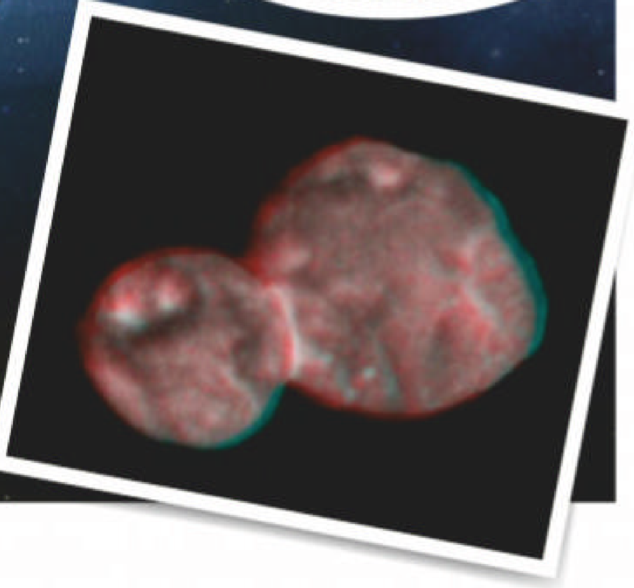

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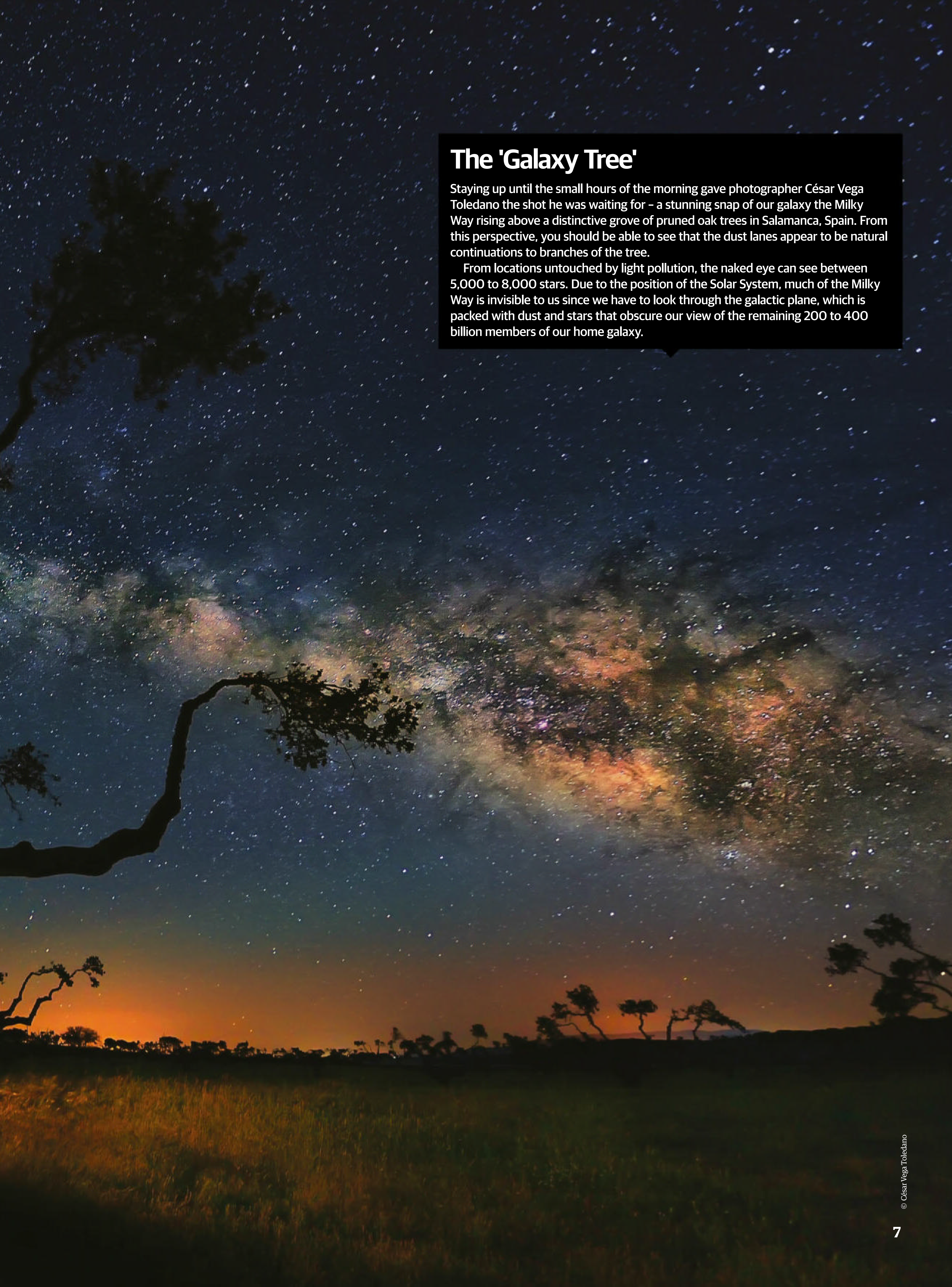

The 'Galaxy Tree'

Staying up until the small hours of the morning gave photographer César Vega Toledano the shot he was waiting for – a stunning snap of our galaxy the Milky Way rising above a distinctive grove of pruned oak trees in Salamanca, Spain. From this perspective, you should be able to see that the dust lanes appear to be natural continuations to branches of the tree.

From locations untouched by light pollution, the naked eye can see between 5,000 to 8,000 stars. Due to the position of the Solar System, much of the Milky Way is invisible to us since we have to look through the galactic plane, which is packed with dust and stars that obscure our view of the remaining 200 to 400 billion members of our home galaxy.

© César Vega Toledano

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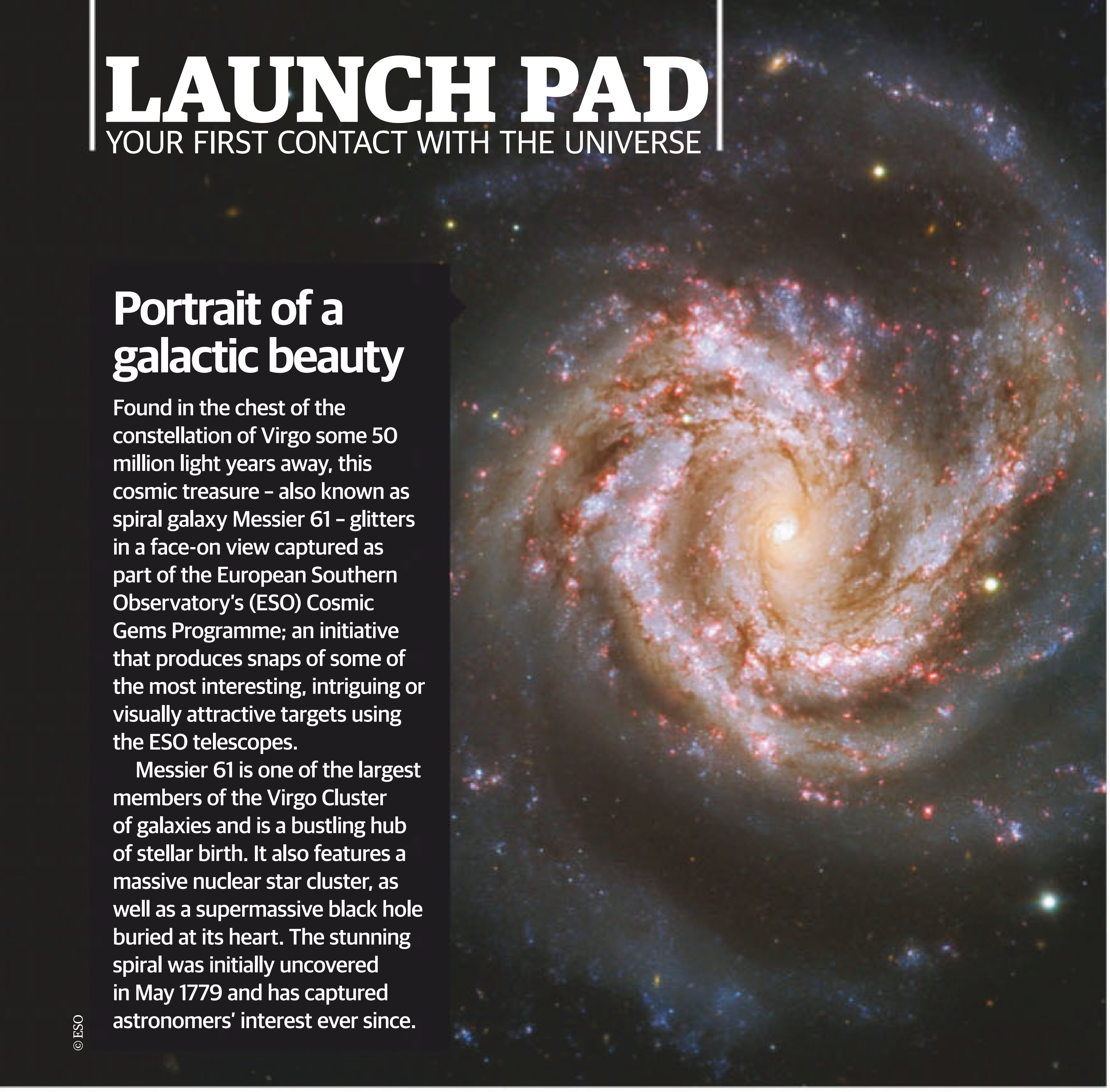

Portrait of a galactic beauty

Found in the chest of the constellation of Virgo some 50 million light years away, this cosmic treasure – also known as spiral galaxy Messier 61 – glitters in a face-on view captured as part of the European Southern Observatory's (ESO) Cosmic Gems Programme; an initiative that produces snaps of some of the most interesting, intriguing or visually attractive targets using the ESO telescopes.

Messier 61 is one of the largest members of the Virgo Cluster of galaxies and is a bustling hub of stellar birth. It also features a massive nuclear star cluster, as well as a supermassive black hole buried at its heart. The stunning spiral was initially uncovered in May 1779 and has captured astronomers' interest ever since.

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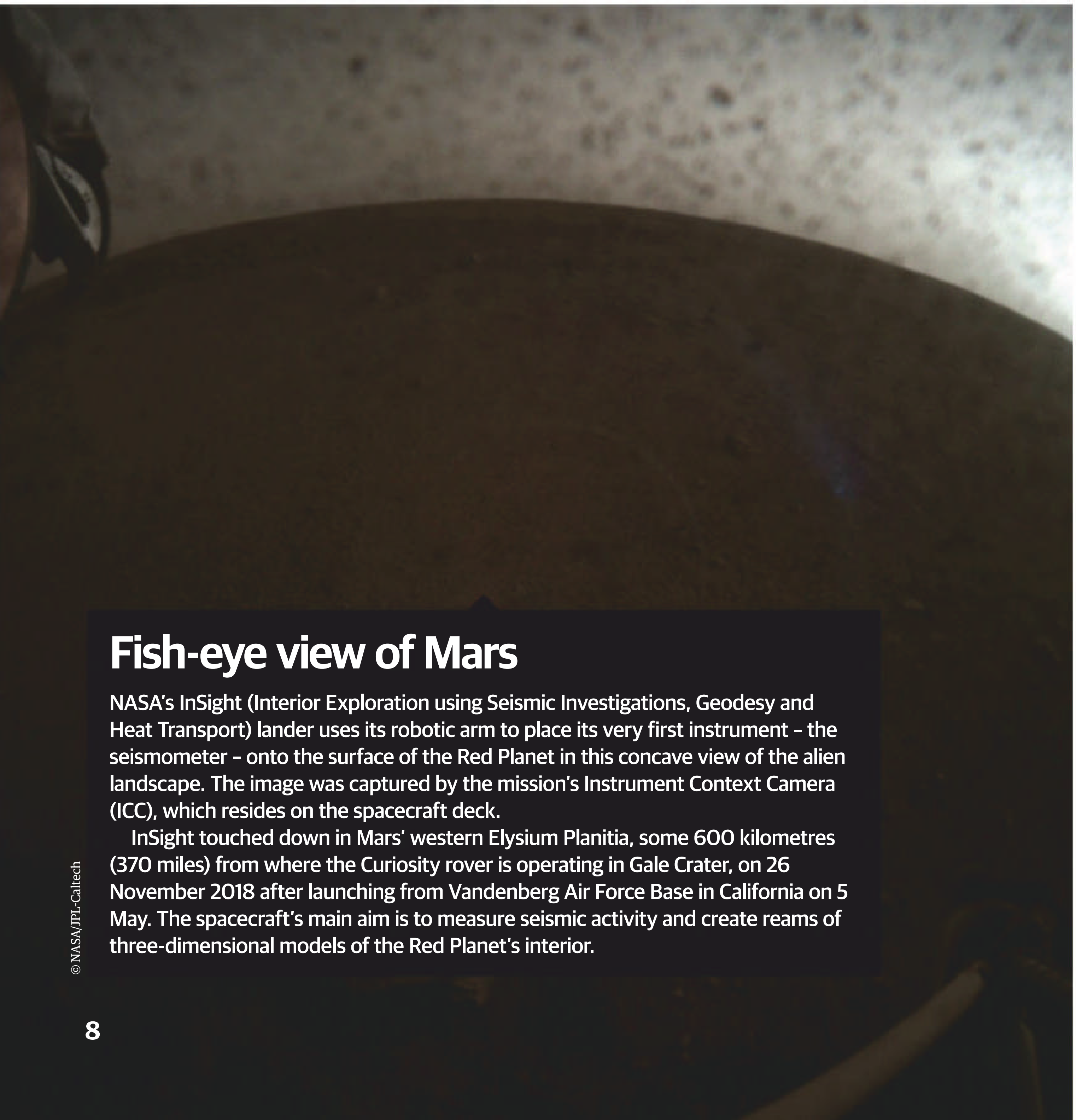

Fish-eye view of Mars

NASA's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) lander uses its robotic arm to place its very first instrument – the seismometer – onto the surface of the Red Planet in this concave view of the alien landscape. The image was captured by the mission's Instrument Context Camera (ICC), which resides on the spacecraft deck.

InSight touched down in Mars' western Elysium Planitia, some 600 kilometres (370 miles) from where the Curiosity rover is operating in Gale Crater, on 26 November 2018 after launching from Vandenberg Air Force Base in California on 5 May. The spacecraft's main aim is to measure seismic activity and create reams of three-dimensional models of the Red Planet's interior.

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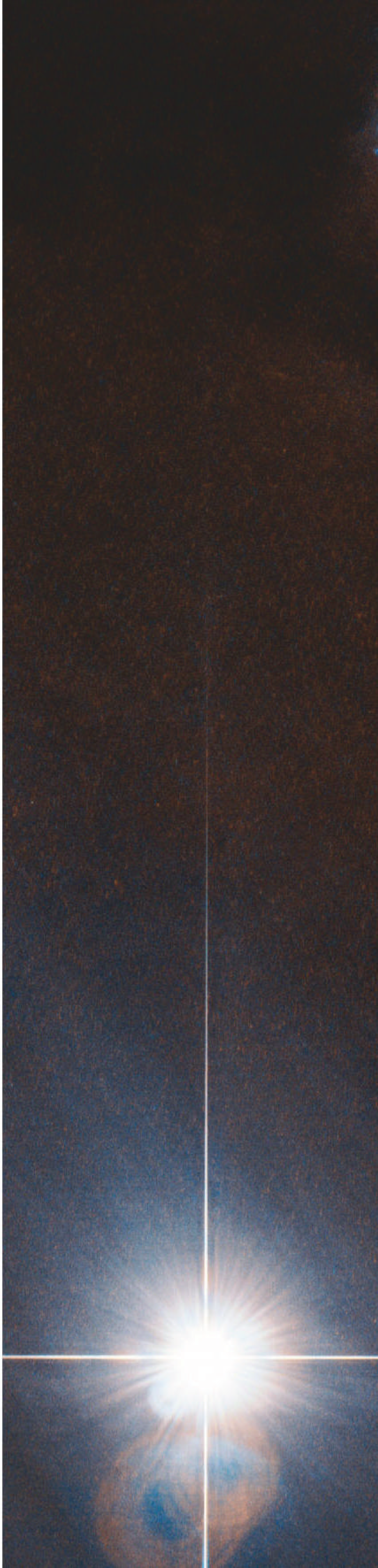

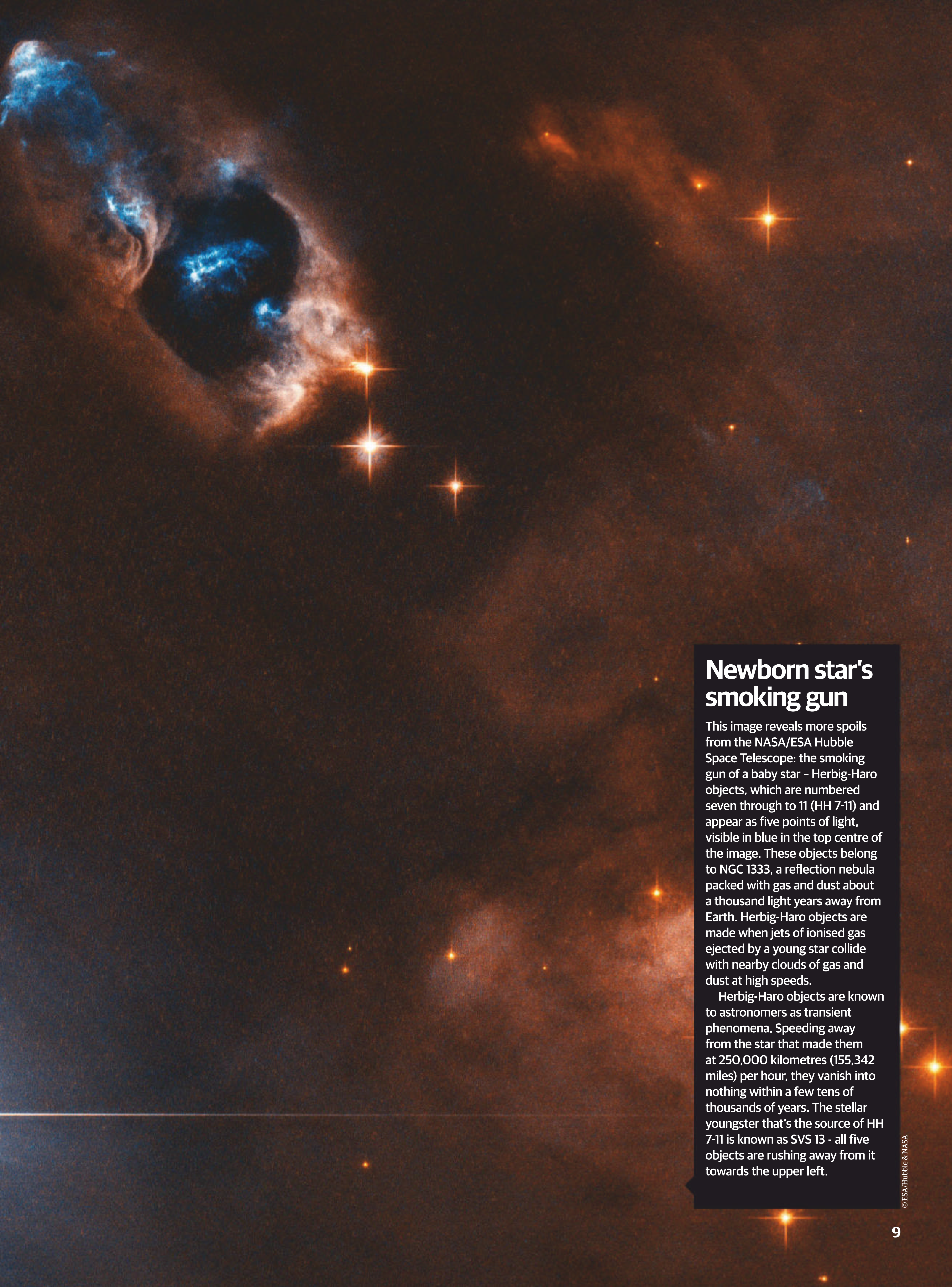

Newborn star's smoking gun

This image reveals more spoils from the NASA/ESA Hubble Space Telescope: the smoking gun of a baby star – Herbig-Haro objects, which are numbered seven through to 11 (HH 7-11) and appear as five points of light, visible in blue in the top centre of the image. These objects belong to NGC 1333, a reflection nebula packed with gas and dust about a thousand light years away from Earth. Herbig-Haro objects are made when jets of ionised gas ejected by a young star collide with nearby clouds of gas and dust at high speeds.

Herbig-Haro objects are known to astronomers as transient phenomena. Speeding away from the star that made them at 250,000 kilometres (155,342 miles) per hour, they vanish into nothing within a few tens of thousands of years. The stellar youngster that's the source of HH 7-11 is known as SVS 13 - all five objects are rushing away from it towards the upper left.

© ESA/Hubble & NASA

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A black hole's cosmic fountain

Abell 2597 is one of many galaxy clusters where astronomers have witnessed gaseous fountains shooting from their centres. At Abell 2597's heart you can find a supermassive black hole; it is here where forces spray most of the gas away before it has a chance to hit the ravenous cosmic behemoth in a cycle that lasts tens of millions of years.

In order to gain the stunning burst of colours scientists used data from the Atacama Large Millimeter/submillimeter Array (ALMA), the Multi-Unit Spectroscopic Explorer (MUSE) on the European Southern Observatory's (ESO) Very Large Telescope (VLT) and NASA's Chandra X-ray Observatory – the result is the first clear evidence for a simultaneous inward and outward flow of gas being driven by a monstrous black hole.

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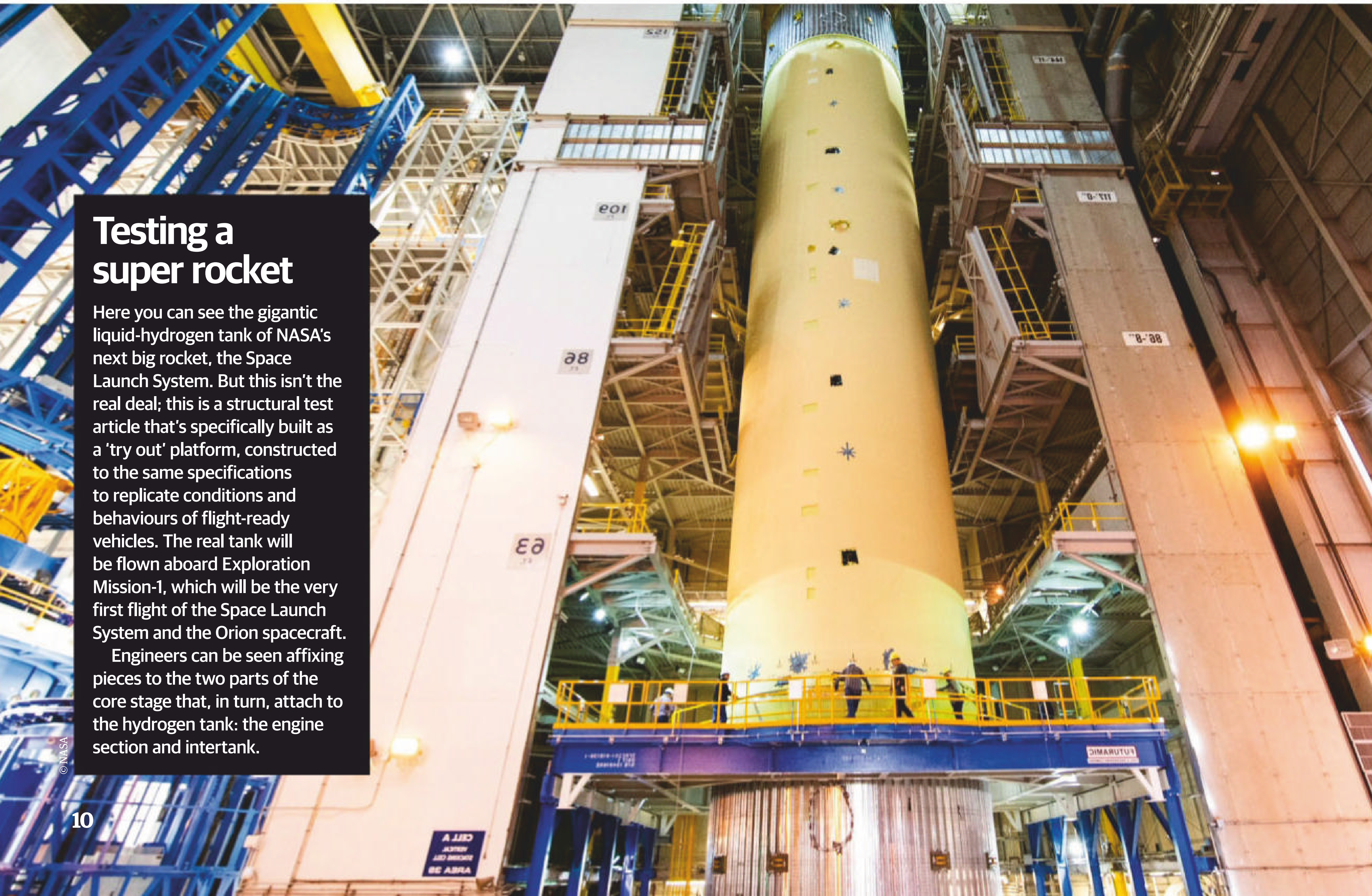

Testing a super rocket

Here you can see the gigantic liquid-hydrogen tank of NASA's next big rocket, the Space Launch System. But this isn't the real deal; this is a structural test article that's specifically built as a 'try out' platform, constructed to the same specifications to replicate conditions and behaviours of flight-ready vehicles. The real tank will be flown aboard Exploration Mission-1, which will be the very first flight of the Space Launch System and the Orion spacecraft.

Engineers can be seen affixing pieces to the two parts of the core stage that, in turn, attach to the hydrogen tank: the engine section and intertank.

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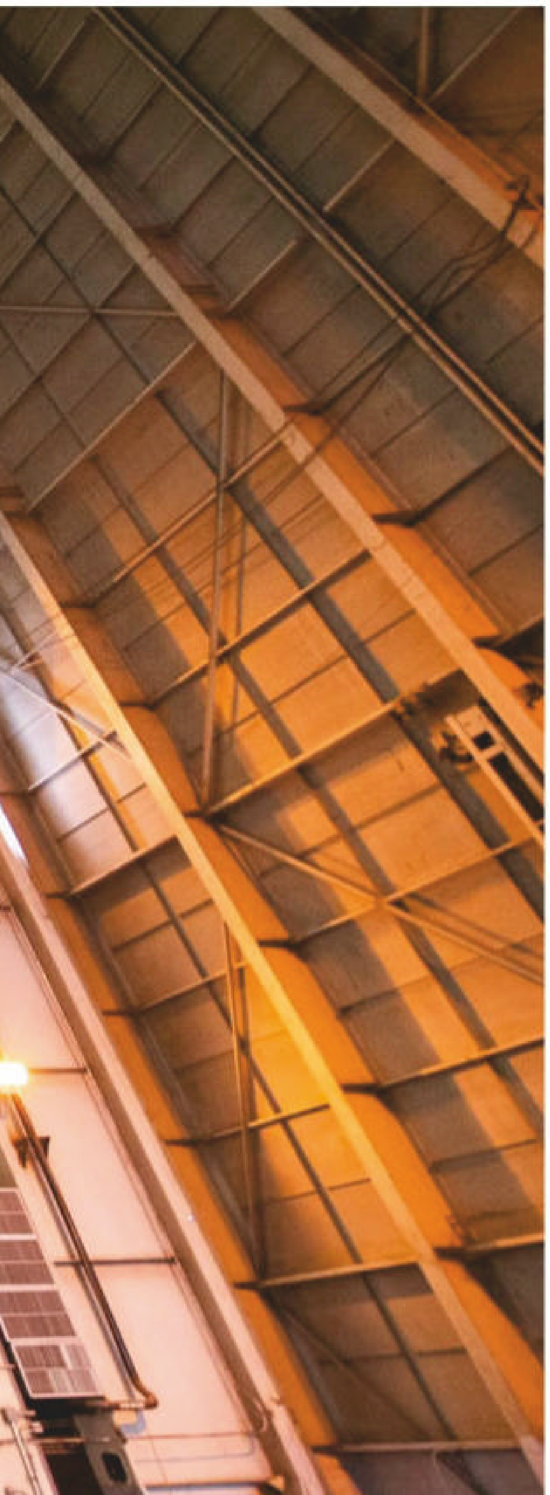
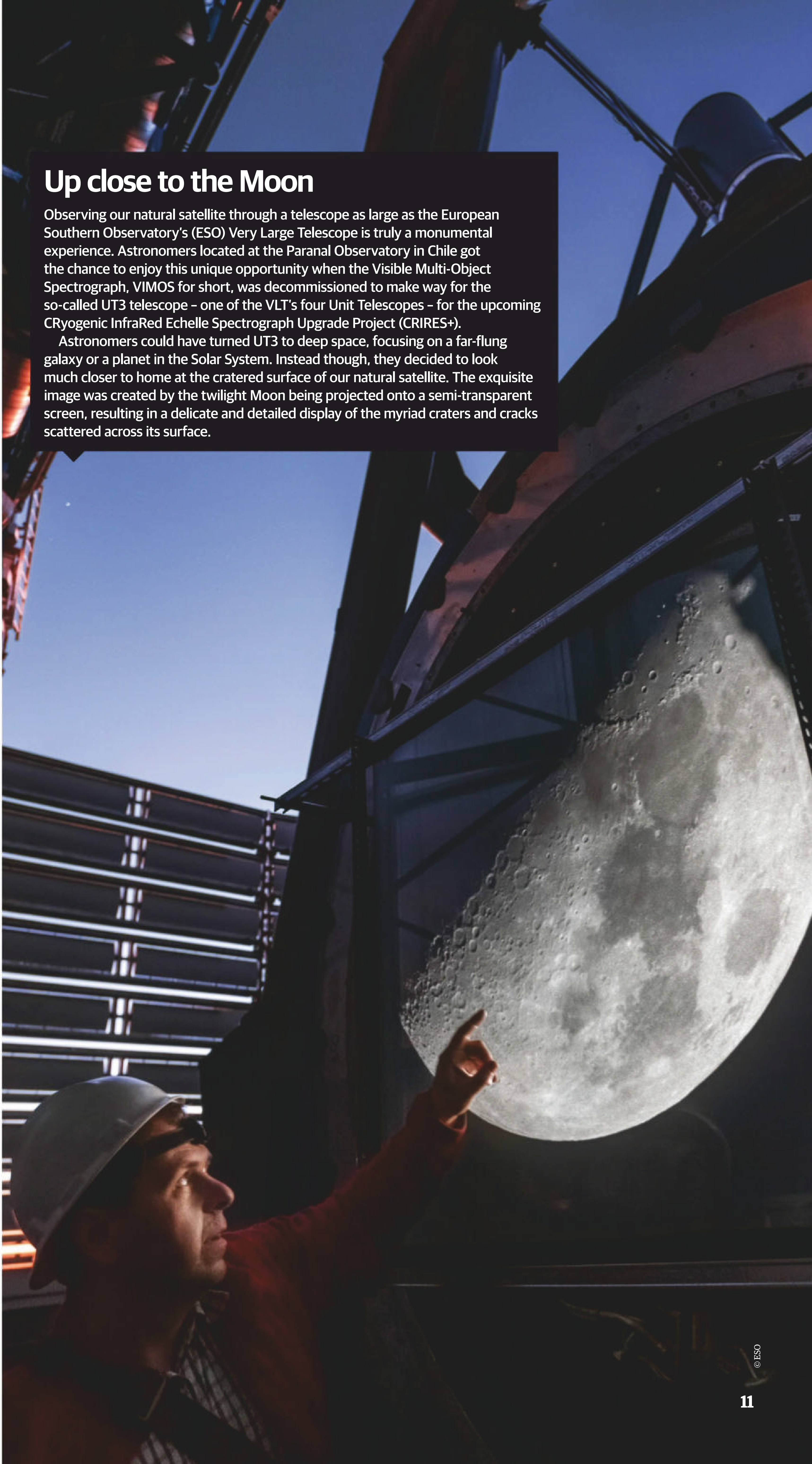


Up close to the Moon

Observing our natural satellite through a telescope as large as the European Southern Observatory's (ESO) Very Large Telescope is truly a monumental experience. Astronomers located at the Paranal Observatory in Chile got the chance to enjoy this unique opportunity when the Visible Multi-Object Spectrograph, VIMOS for short, was decommissioned to make way for the so-called UT3 telescope – one of the VLT's four Unit Telescopes – for the upcoming CRyogenic InfraRed Echelle Spectrograph Upgrade Project (CRIRES+).

Astronomers could have turned UT3 to deep space, focusing on a far-flung galaxy or a planet in the Solar System. Instead though, they decided to look much closer to home at the cratered surface of our natural satellite. The exquisite image was created by the twilight Moon being projected onto a semi-transparent screen, resulting in a delicate and detailed display of the myriad craters and cracks scattered across its surface.



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TESS was launched in April 2018 to search for exoplanets

> "HD 21749b seems to be made of denser stuff than the gaseous worlds we're used to"

Weird 'sub-Neptune' exoplanet found by TESS

Words by **Mike Wall**

The Transiting Exoplanet Survey Satellite (TESS) has discovered a planet orbiting the star HD 21749, which lies about 53 light years from Earth in the faint constellation Reticulum, scientists have announced.

The world, known as HD 21749b, is a weirdo - at least by the standards of our own Solar System. It's a 'sub-Neptune' about three-times bigger than Earth, which means it's likely gaseous rather than rocky. But HD 21749b seems to be made of denser stuff than the gaseous worlds we're used to, because it's 23-times more massive than Earth.

"We think this planet wouldn't be as gaseous as Neptune or Uranus, which are mostly hydrogen and really puffy," discovery team leader Diana Dragomir of the Massachusetts Institute of Technology's Kavli Institute for Astrophysics and Space Research said. "The planet likely has a density of water, or a thick atmosphere."

HD 21749b completes one orbit of its host star, which is nearly as bright as our Sun, every 36 Earth days. The exoplanet likely has an average surface temperature around 150 degrees Celsius (300 degrees Fahrenheit), discovery team members said.

The researchers also detected hints of another, smaller planet in the system, a planet that would have an orbital period of 7.8 days. If this world is confirmed it will be the first roughly Earth-size planet found by TESS.

TESS launched to Earth orbit in April 2018 on a mission to find alien worlds circling stars in our Solar System's neighbourhood. Like NASA's recently deceased Kepler space telescope, which is responsible for about 70 per cent of all known exoplanet discoveries to date, TESS uses the transit method. That is, it looks for tiny dips in starlight caused when planets cross their host stars' faces from the satellite's perspective.

This shifting focus makes it tough for TESS to find planets that lie far from their host stars and therefore take a long time to complete one orbit. Indeed, HD 21749b is very far-flung for TESS; two other smallish worlds found by the mission have orbital periods of 11 hours and 6.3 days respectively.

"It's the coolest small planet that we know of around a star this bright," Dragomir said. "We know a lot about atmospheres of hot planets, but because it's very hard to find small planets that orbit farther from their stars and are therefore cooler, we haven't been able to learn much about these smaller, cooler planets. Here we were lucky and caught this one and can now study it in more detail."

© NASA; ESA; Jingchuan Yu, Beijing Planetarium

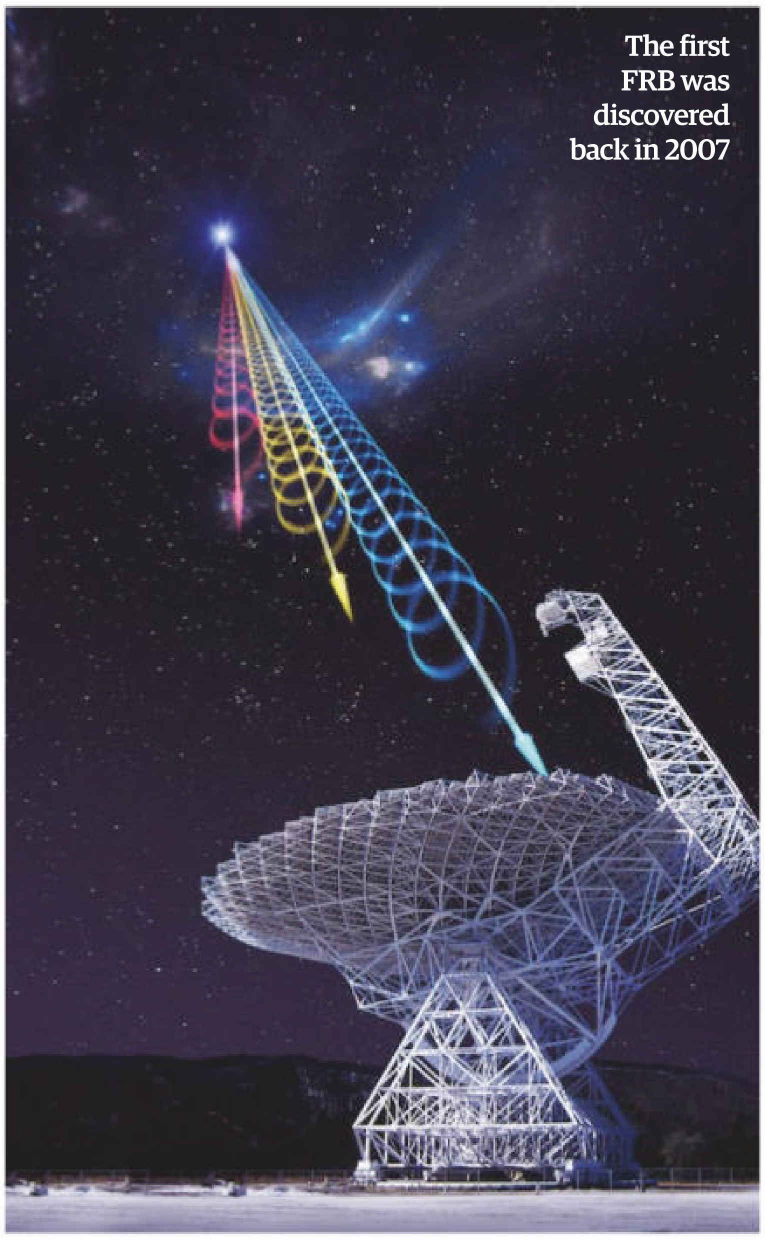
Mysterious deep-space flashes uncovered

Words by **Mike Wall**

Astronomers have spotted 13 more of these extragalactic light flashes, known as fast radio bursts (FRB), and the new haul includes the second repeating FRB ever discovered. "Knowing that there is another [repeater] suggests there could be more out there," said Ingrid Stairs, an astrophysicist at the University of British Columbia. "And with more sources for study we may be able to understand these cosmic puzzles - where they're from and what causes them."

FRBs are brief but incredibly powerful phenomena; the millisecond emissions are energetically comparable to the total output of our Sun over a century. But, as Stairs noted, FRBs are as enigmatic as they are spectacular. Astronomers have offered a number of possible explanations for the bursts, including merging neutron stars and advanced alien civilisations. The discovery team analysed observations by the Canadian Hydrogen Intensity Mapping Experiment (CHIME), an advanced new radio telescope in British Columbia's Okanagan Valley. Yet the telescope wasn't even fully up and running when it made the new detections.

Astronomers now know that FRB "sources can produce low-frequency radio waves. Those low-frequency waves can escape their environment and are not too scattered to be detected by the time they reach the Earth," CHIME team member Tom Landecker said. "That tells us something about the environments and the sources,' Landecker added. "We haven't solved the problem, but it's several more pieces in the puzzle."



The first FRB was discovered back in 2007

Sun will turn into giant crystal ball after death

Words by **Mike Wall**

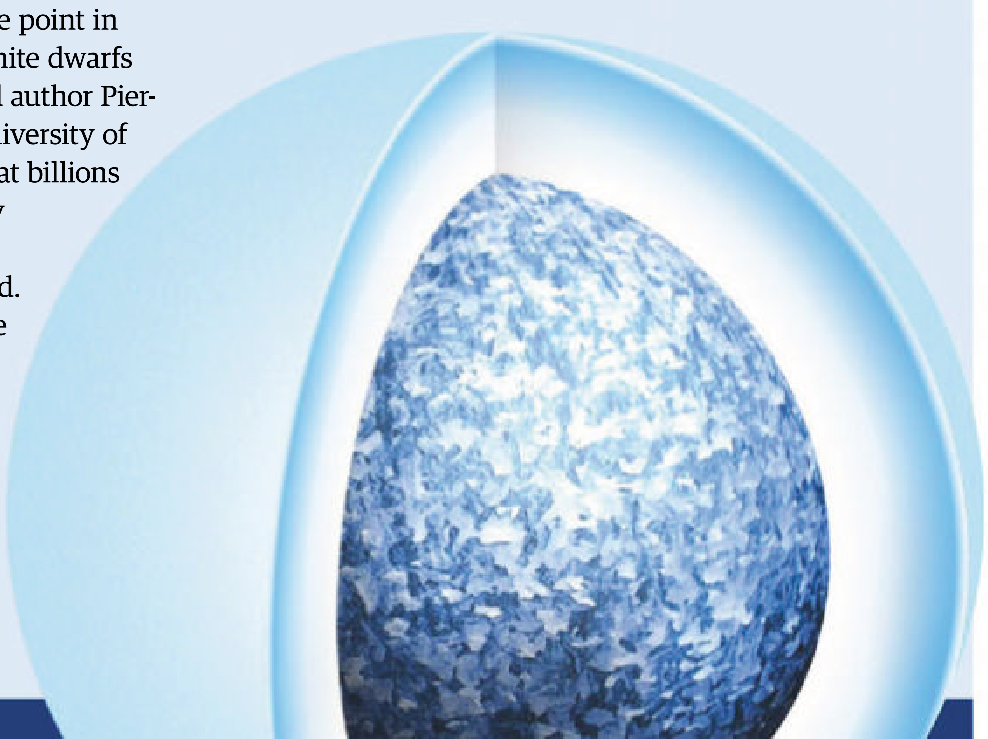
Like the vast majority of stars in our Milky Way galaxy, the Sun will eventually collapse into a white dwarf, an exotic object about 200,000-times denser than Earth. To put that in perspective, a mere teaspoon of white dwarf material would weigh about as much as an elephant if you could somehow transport the stuff to our planet.

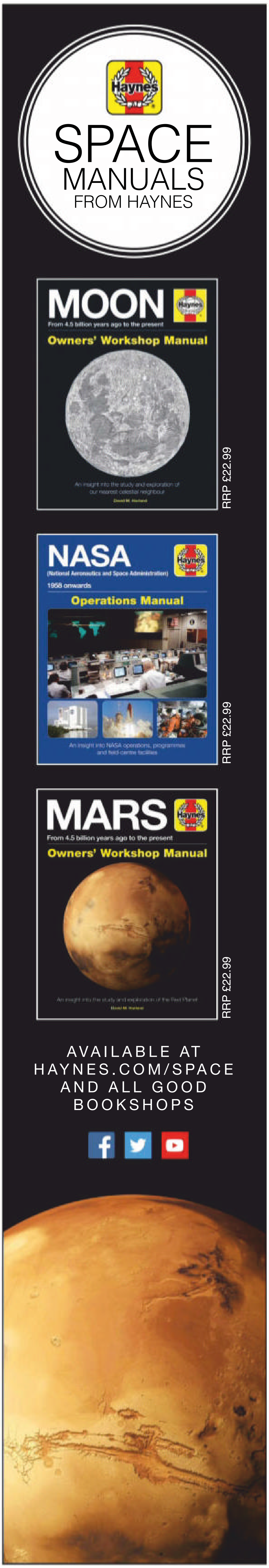
Half a century ago theorists predicted that white dwarfs solidify into crystal over time - and new research has found that this is indeed the case.

"All white dwarfs will crystallise at some point in their evolution, although more massive white dwarfs go through the process sooner," study lead author Pier-Emmanuel Tremblay, a physicist at the University of Warwick in England, said. "This means that billions of white dwarfs in our galaxy have already completed the process and are essentially crystal spheres in the sky," Tremblay added. "The Sun itself will become a crystal white dwarf in about 10 billion years."

Tremblay and his colleagues analysed data gathered by the European Space Agency's Gaia spacecraft which launched in December 2013 to help researchers construct the best-ever 3D map of the Milky Way. Gaia does this by precisely monitoring the positions of huge numbers of stars; the mission team aims to study 1 billion stars over the spacecraft's operational lifetime.

"This is the first direct evidence that white dwarfs crystallise, or transition from liquid to solid," Tremblay said. "It was predicted 50 years ago that we should observe a pile-up in the number of white dwarfs at certain luminosities and colours due to crystallisation, and only now this has been observed."





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An artist's impression of NASA's Voyager 1

'Wild' interstellar probe mission idea gains momentum

Words by **Leonard David**

With the goal of reaching 145 billion kilometres (90 billion miles) from the Sun, the proposed robotic explorer would push the limits of engineering know-how and space technology, advocates say.

The Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, is leading an international look at this prospect with a team of scientists and engineers studying a mission to the virtually unexplored space beyond our Sun's sphere of influence.

"Overall I think the study is progressing well and will provide some good and solid input for the next Decadal Survey round," said APL's Ralph McNutt, interstellar probe study leader and principal investigator. The Decadal Survey is based on studies led by the US National Academies to provide a science community consensus on new undertakings in NASA space science and exploration.

Interstellar probes and interstellar precursor missions are not new, McNutt explained, "but have lacked traction with policymakers and the scientific community at large because of the states of both scientific knowledge and engineering realities".

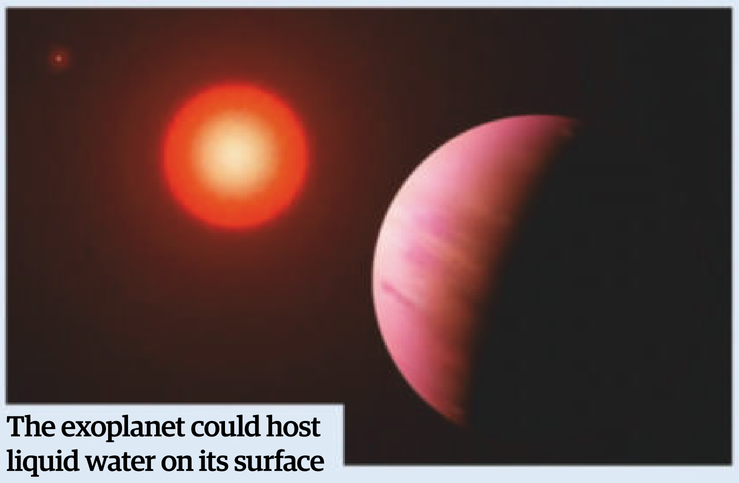
Moreover, he explained that the next step in reaching to the stars will require the recognition of engineering limits, scientific trades and scientific compromises, "but this is new neither in science nor exploration. Such a step would be an interstellar probe. The time for that step has come."

Distant, 'potentially habitable' planet spotted by citizen scientists

Words by **Samantha Mathewson**

Citizen scientists have unveiled a distant exoplanet that is believed to be roughly twice the size of Earth and located within its star's habitable zone. The exoplanet, named K2-288Bb, could either be a rocky world like Earth or a gas-rich planet like Neptune. Using data from NASA's Kepler space telescope, the new world was found 226 light years from Earth in the constellation Taurus, according to NASA.

"It's a very exciting discovery due to how it was found, its temperate orbit and because planets of this size seem to be relatively uncommon," Adina Feinstein, lead scientist of the study, said. The new world lies in a stellar system called K2-288 which includes two dim, cool M-type stars that are roughly 8.2 billion kilometres (5.1 billion miles) apart – about six-times the distance between Saturn and the Sun.



The exoplanet could host liquid water on its surface

The brighter star of the pair is estimated to be half as large and massive as Earth's Sun, while its dimmer companion is about one-third the Sun's mass and size. K2-288Bb orbits the smaller and dimmer star every 31.3 days. Furthermore, the data suggests that K2-288Bb resides within its host star's habitable zone, which means the planet may have liquid water on its surface.

The exoplanet was discovered using data from the fourth observing campaign of Kepler's K2 mission, which ran from 2014 to 2018. Specifically, the research team looked for evidence of periodic changes in stars' brightness which would suggest that an exoplanet passed in front of one of the stars. Using this method the team found evidence of two likely planetary transits in the K2-288 system. Observations of a third transit were needed to confirm the discovery of an exoplanet.

It turned out the team was not utilising all of the spacecraft's data. During its K2 mission Kepler repositioned itself towards a new patch of sky once every three months. There were initial concerns about the accuracy of Kepler's measurements collected during the first few days after it was reoriented in the sky. "That's how we missed it - and it took the keen eyes of citizen scientists to make this extremely valuable find and point us to it," Feinstein said.

Musk: SpaceX 'Starship' hopper to make test flight 'within weeks'

Words by **Mike Wall**

The flight-test version of SpaceX's Starship vehicle could be ready to take its first short 'hopping' excursion in a matter of weeks, company founder and CEO Elon Musk has said in a statement.

"Aiming for four weeks, which probably means eight weeks, due to unforeseen issues," Musk tweeted in January when asked by a follower when the first hopper test would take place.

SpaceX is developing Starship and a giant rocket called the Super Heavy to take people to and from the Moon, Mars and other destinations throughout the Solar System.

The first crewed Red Planet mission for the rocket and 100-passenger Starship could come as early as the mid-2020s if development and testing go well, Musk has said.

This work is taking place at both SpaceX headquarters in Hawthorne, California, and the company's test site in South Texas near the border city of Brownsville. The hopper flights will take off from this latter facility.

When they're up and running both Starship and the Super Heavy will rely on SpaceX's powerful Raptor engine, which is currently in development. The engines on the Starship test vehicle will be "a blend of Raptor development and operational parts," Musk explained. The first of these hopper engines will probably be test-fired next month, he added.

Illustrations of the craft show a three-finned, retro design

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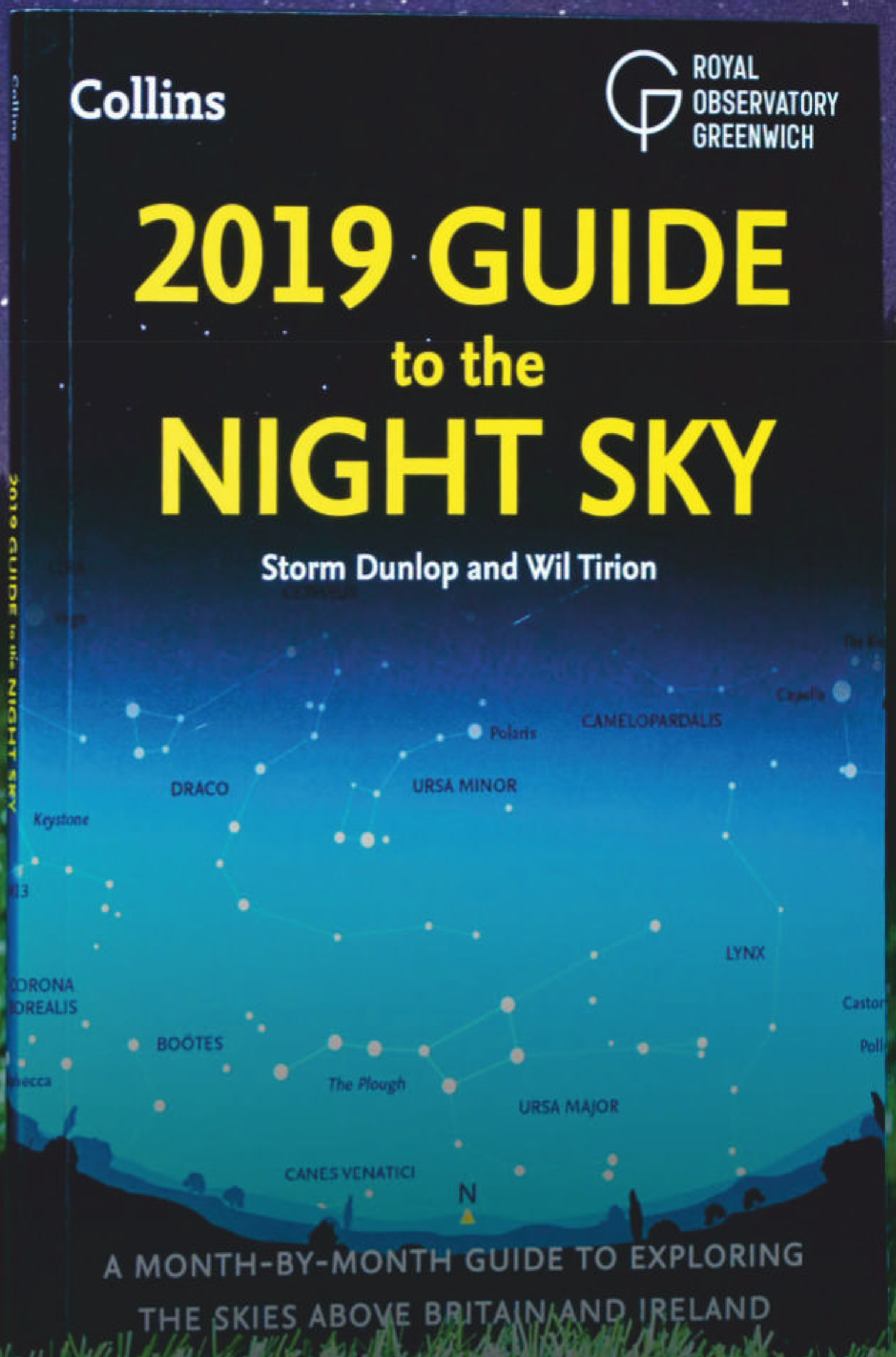

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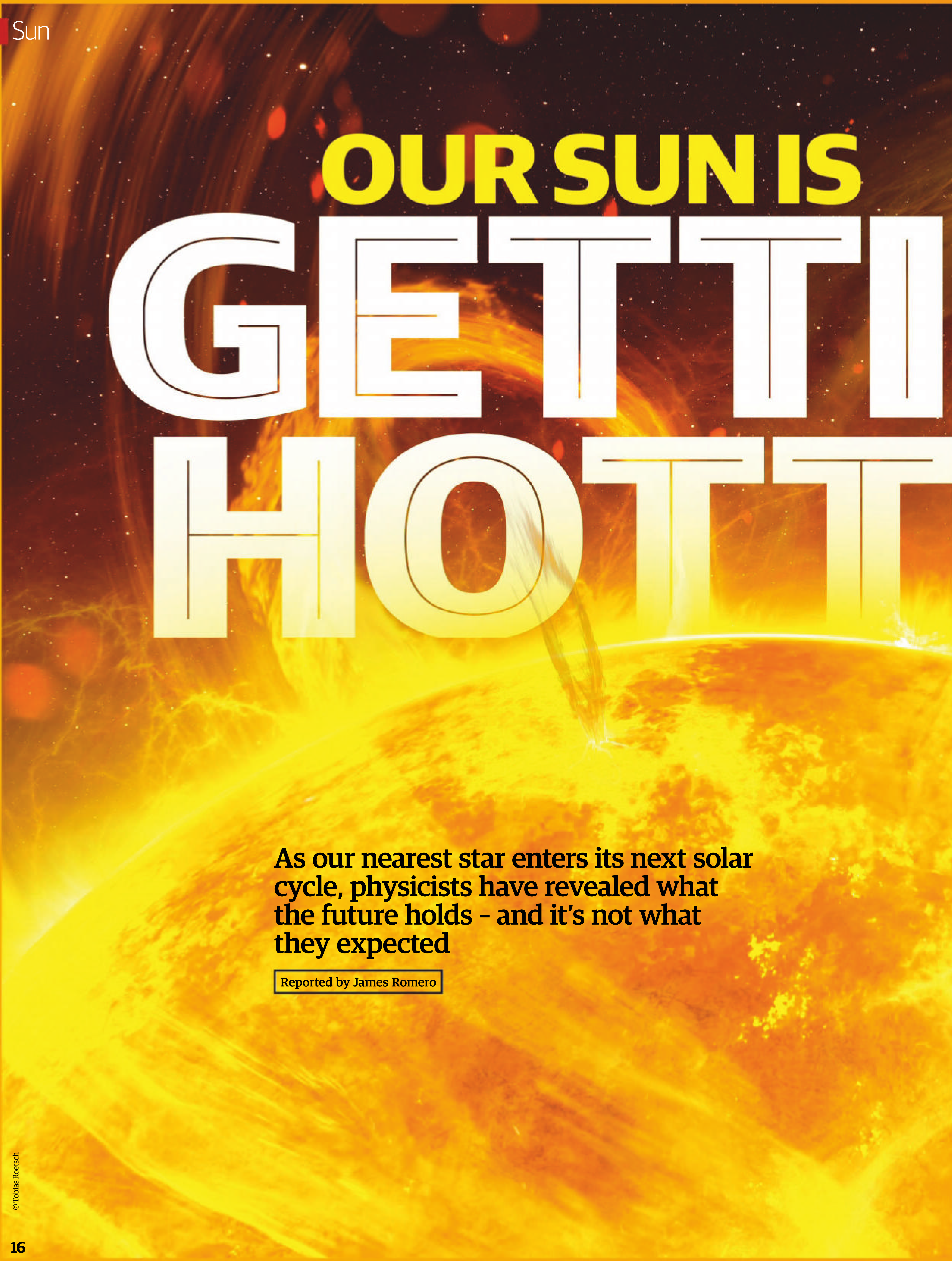

OUR SUN IS GETTI HOTT

As our nearest star enters its next solar cycle, physicists have revealed what the future holds – and it's not what they expected

Reported by James Romero

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As a life-giver that warms and lights up our world, it is easy to forget the true, violent nature of the Sun. As the Sun enters a new cycle of surface activity, we are only now beginning to fully appreciate the wide-ranging ways our star's changeable nature can impact our planet and modern lives.

Solar weather describes the influence of the Sun on the Earth-space environment. Back in 2011 it was added to the UK government's National Risk Register and placed on a similar level to the emergence of a new disease due to the number of people it could potentially impact on Earth.

"The Sun is very dynamic," says Helen O'Brien, lead engineer on the European Space Agency's Solar Orbiter mission. "It has different moods, it is very explosive and it has the potential to damage our modern infrastructure." As well as providing heat and light, our star is constantly throwing out more deadly material. The solar wind is the name given to this constant stream of energised, charged particles, primarily electrons and protons.

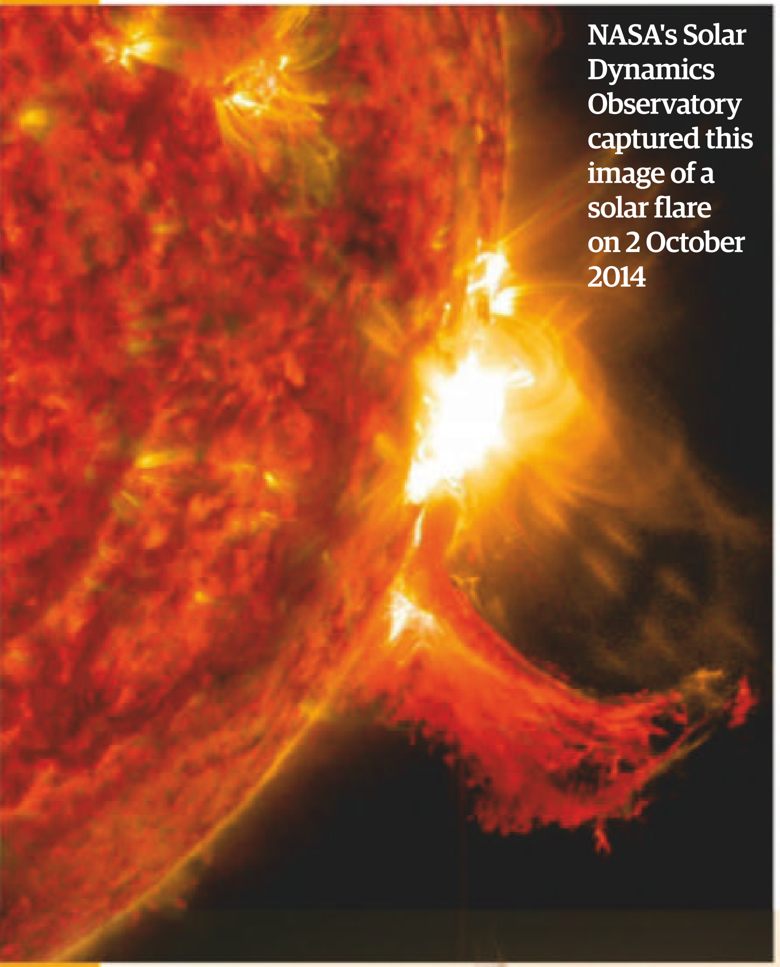
On Earth we are shielded by our planet's magnetic field while high-energy X-rays and ultraviolet light are absorbed high up in the atmosphere. They electrify their surroundings to create the Earth's ionosphere and simultaneously excite constituents of our own atmosphere so they glow and create the famous aurorae.

While the aurorae are harmlessly enjoyed by polar communities and tourists, the Sun's own magnetic field can throw far more violent eruptions our way. Its much larger field is composed of a series of magnetic lines that connect distant points on the surface. Over time these lines can become twisted as the Sun's compositional fluidity sees material at its equator rotate faster than at its poles, and the magnetic field gets wrapped around the star. "When you distort a magnetic field it is like stretching an elastic band," says Chris Scott, professor of Space and Atmospheric Physics at the University of Reading. "You are storing up energy."

> "[The Sun] is very explosive and has the potential to damage our modern infrastructure"
>
> **Helen O'Brien**

Those magnetic distortions cause complex knots to form, which burst to the surface as sunspots. When the Sun is very active you have lots of energy stored up in these knots, and occasionally the system will reconfigure itself through solar flares that throw out vast quantities of high-energy plasma like a cloud from the Sun's atmosphere.

These eruptions can be incredibly violent. The largest, known as coronal mass ejections, can contain billions of tonnes of material, which travels out at speeds of several million miles per hour.



NASA's Solar Dynamics Observatory captured this image of a solar flare on 2 October 2014

If Earth is in the crosshair of these large storms the consequences can be both spectacular and costly. This was evident even back in September 1859 on the night of the most famous direct hit, known as the Carrington event, which bathed almost the entire surface of the Earth in beautiful aurorae. Though Carrington was spectacular in its scale and spectacle, it was also the first example of solar weather impacting our technology - recently rolled out telegraph systems in America and Europe were hit by fires and gave people electric shocks.

In today's information age of integrated power networks and satellite communications, a similar strike today could bring down radio communications and upset electronics on the ground, causing long-distance power grids to fail. In 1989 a coronal mass ejection blacked out the entire Canadian province of Quebec, while last year an economic risk assessment by researchers from the University of Oxford found that a Carrington-style event could leave the UK with £15.9 billion (approximately $20.5 billion) worth of damage.

In general, a direct threat to human life on the Earth's surface is low. However, a small proportion of our population are spending more and more time higher up, and that does create risks. Storms increase the radiation impacting spacecraft to levels that could threaten astronaut health, while more transatlantic flights are crossing the poles where solar wind material is constantly funnelled by Earth's magnetic field.

Exposure from a single flight during normal solar conditions will be tiny, but there is concern for flight staff working up there year round. Also, recent research from Clive Dyer of the University of Surrey Space Centre suggests flying in modern aircraft

> "A strike today could bring down radio communications and upset electronics on the ground, causing power grids to fail"

What's going to happen to the Sun?

Each layer of our home star is affected in the cycle change

Sun's magnetic field
The magnetic field transitions from a simple arrangement at solar minimum to a complex tangled web as it wraps around the Sun, though recent cycles haven't produced the same intensity of maximum.

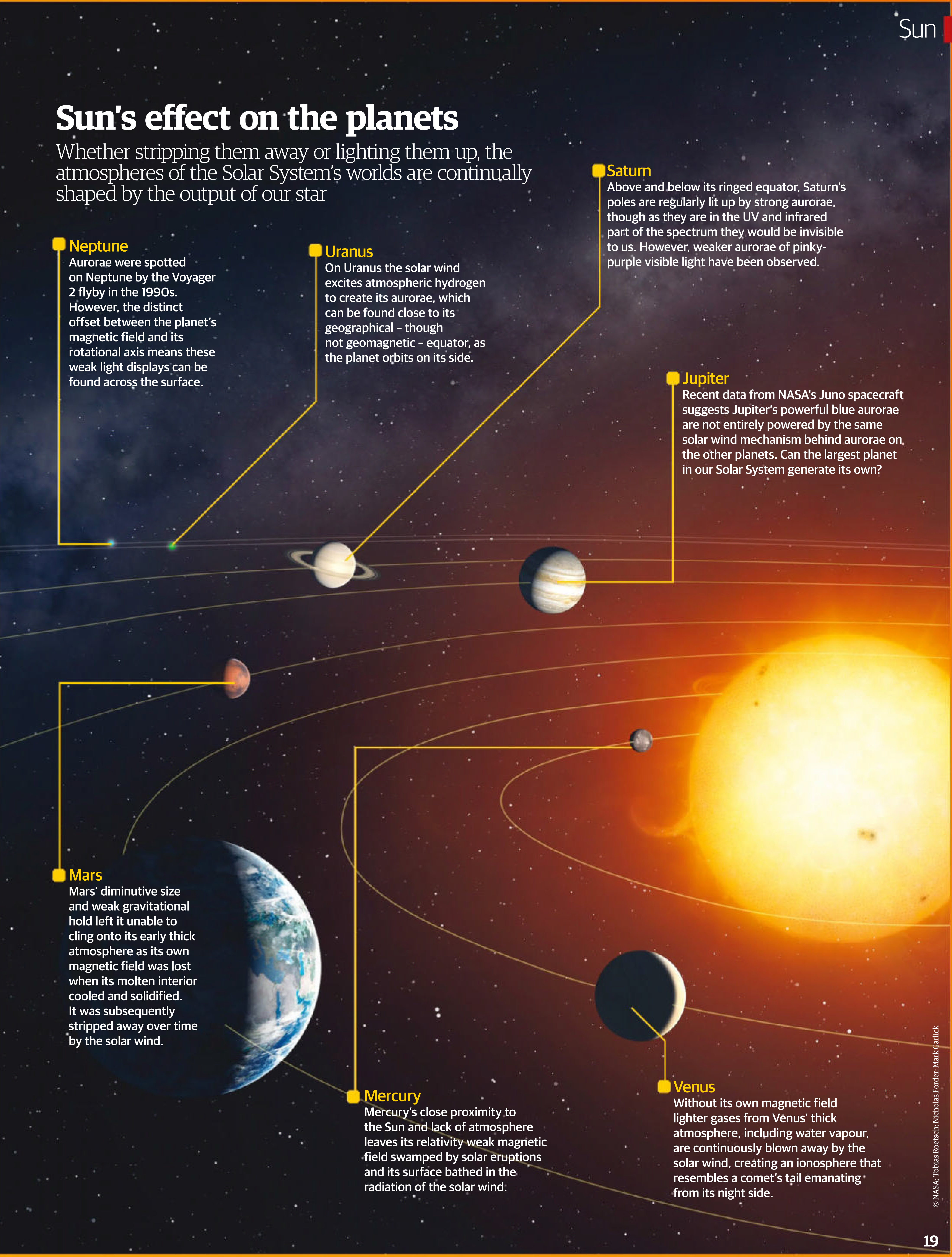
Corona
Though generally marked by lower output, solar minimums can still see heightened periods of high-energy particles released from this upper-atmospheric layer as the Sun's magnetic field creates holes in the corona. However, it's during the solar maximum when the corona will be most active, full of spinning tornados, nanoflares and looped-shaped helmet streamers. As you move towards solar maximum solar flares push more frequently through the corona, heating its gas up.

Photosphere
On the surface of the lowest layer of the Sun's atmosphere, the start of a new cycle is marked by the appearance of sunspots in higher latitudes. Solar flares also become much more common as you approach solar maximum.

Chromosphere
The second of the Sun's three atmospheric layers experiences frequent heating by ascending solar flares as you approach the solar maximum. Solar prominences, gigantic plumes of gas rising up from the photosphere, are also more abundant at solar maximum and during louder solar cycles. As are spicules, jet eruptions of gas that shoot upwards and outwards into the corona.

Sun's effect on the planets

Whether stripping them away or lighting them up, the atmospheres of the Solar System's worlds are continually shaped by the output of our star



Neptune
Aurorae were spotted on Neptune by the Voyager 2 flyby in the 1990s. However, the distinct offset between the planet's magnetic field and its rotational axis means these weak light displays can be found across the surface.

Uranus
On Uranus the solar wind excites atmospheric hydrogen to create its aurorae, which can be found close to its geographical – though not geomagnetic – equator, as the planet orbits on its side.

Saturn
Above and below its ringed equator, Saturn's poles are regularly lit up by strong aurorae, though as they are in the UV and infrared part of the spectrum they would be invisible to us. However, weaker aurorae of pinky-purple visible light have been observed.

Jupiter
Recent data from NASA's Juno spacecraft suggests Jupiter's powerful blue aurorae are not entirely powered by the same solar wind mechanism behind aurorae on the other planets. Can the largest planet in our Solar System generate its own?

Mars
Mars' diminutive size and weak gravitational hold left it unable to cling onto its early thick atmosphere as its own magnetic field was lost when its molten interior cooled and solidified. It was subsequently stripped away over time by the solar wind.

Mercury
Mercury's close proximity to the Sun and lack of atmosphere leaves its relativity weak magnetic field swamped by solar eruptions and its surface bathed in the radiation of the solar wind.

Venus
Without its own magnetic field lighter gases from Venus' thick atmosphere, including water vapour, are continuously blown away by the solar wind, creating an ionosphere that resembles a comet's tail emanating from its night side.

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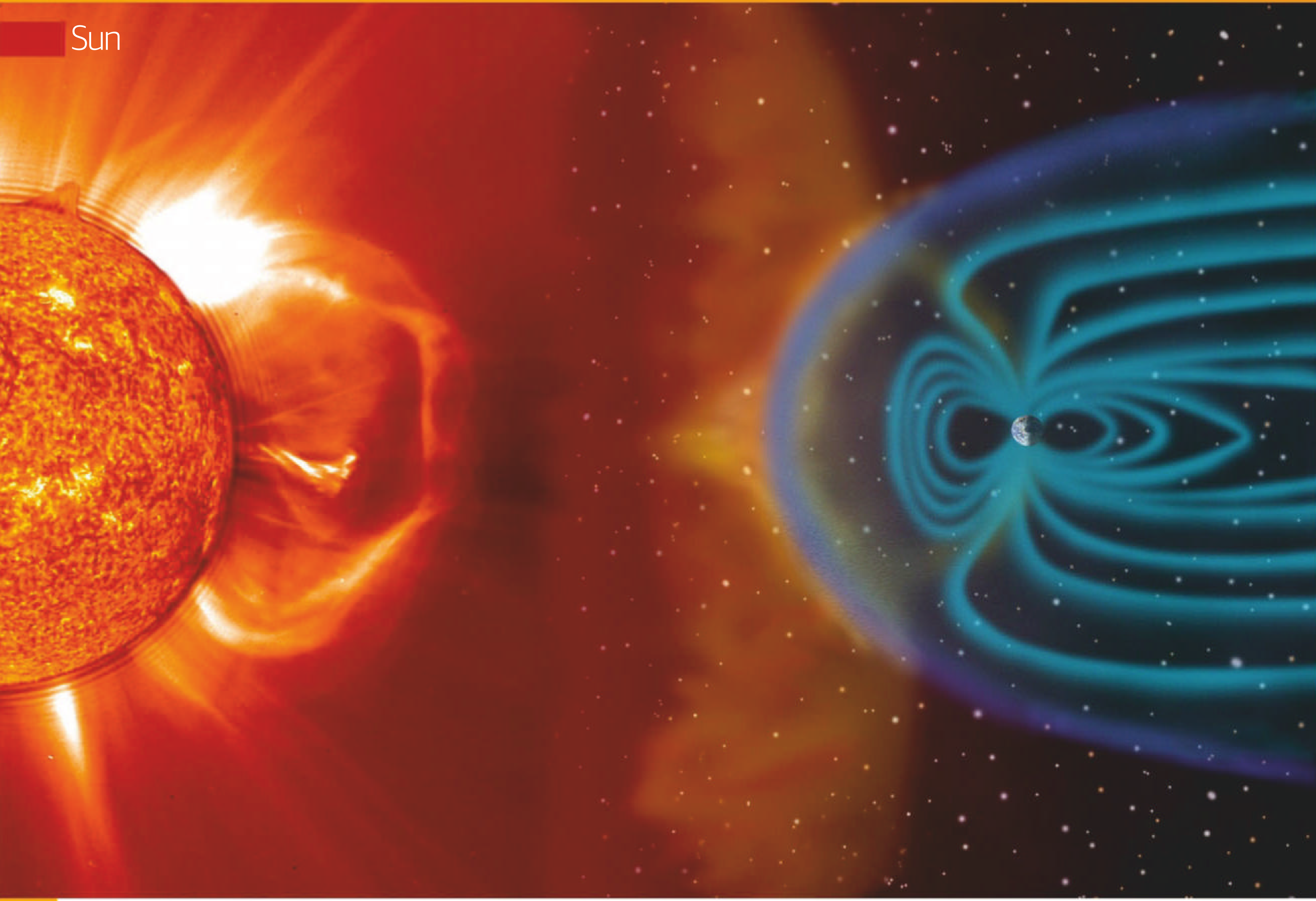
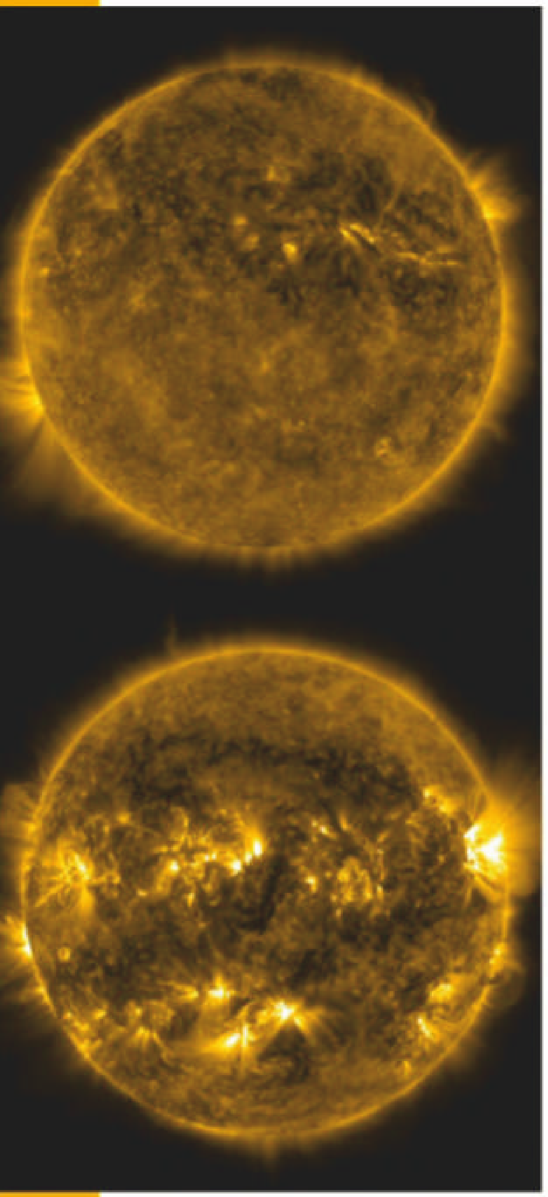




during a solar storm could expose passengers to radiation levels equivalent to the annual working limit for air crews. This threat has left satellite companies, aircraft operators and power companies monitoring the solar cycle for clues as to when the threat level will be at its highest.

By counting sunspots on the Sun's surface scientists have for some time known of 11-year cycles of increasing and decreasing solar activity and surface eruptions, driven by the tangling and untangling of the magnetic field lines. These plots indicate we are approaching the latest solar minimum, and therefore entering a new cycle.

Recent magnetic field evolution models developed by the Center of Excellence in Space Sciences in India concluded that the solar maximum of the next cycle, solar cycle 25, will occur around 2024. They also suggested the cycle could buck a wider trend of decreasing solar maximum intensities since the early 1990s, though perhaps not in a way that would greatly threaten ground- or space-based infrastructure.

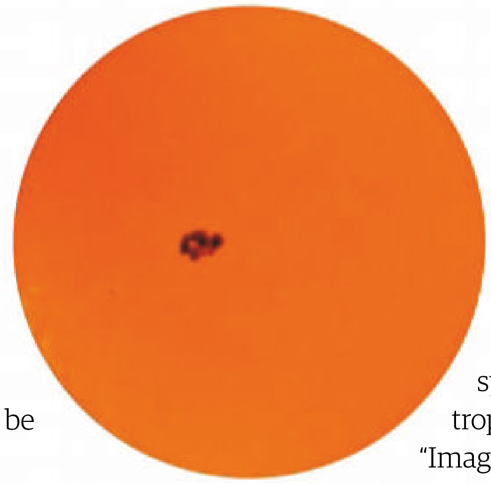
"It is unlikely that this will affect big solar storms, as these can happen at any stage of the solar cycle," says Scott. However, anticipating the timing and severity of the coming solar cycle could help us prepare for the more local effects such solar variability that effect our lives and which have only come to light in the last decade or two.

Researcher Pablo Mauas has published a series of papers analysing river flows of the Paraná River, as well as measuring snow accumulation and counting tree rings to establish a remarkable agreement between local precipitation rates and the number of sunspots, tracked back over many decades. "I can quite believe there is an 11-year cycle in the flow rates of the river," says Scott, who points to evidence of similar solar-influenced systems closer to home.

During recent low periods of solar activity it seems the jet streams become more meandering, and you get more 'blocking events' where air-pressure systems get stuck over a certain location. These phenomena are thought to account for some of the very cold recent winters in northwest Europe, but perhaps this trend may reverse slightly if the next solar cycle is more active, as the Indian research team suggests.

In his own research Scott has shown that fast jets of solar wind passing the Earth, associated with more active solar periods, can result in a substantial increase in lightning strikes across Europe for up to 40 days as a result of disturbances to the electrical properties of the atmosphere. While communities and populations may need to adapt to changes in these localised weather systems, a better way of predicting larger scale solar weather on a more detailed day-to-day basis is an urgent priority.

This becomes more pressing if Carrington events prove to be more common than that 'once-in-a-century' tag. Reanalysis of magnetic behaviour measurements in the Earth's atmosphere by Scott's colleague Mike Lockwood has found storms in



1941 and 1972 that may have been as big, if not bigger, than Carrington, but had surprisingly little impact. "It might be that the biggest parts occurred over parts of the world where there wasn't the technological infrastructure to be disturbed," says Scott.

There was also a storm in July 2012 that narrowly missed the Earth and fortunately hit a solar-observation spacecraft from the Solar TErrestrial RElations Observatory (STEREO) mission. It was travelling fast enough that if it had been on target it would have triggered a modern-day Carrington-like event. If we are not to be so fortunate during the next solar cycle we will need to investigate ways to provide more detailed forecasts of what is coming at us.

"It's like on Earth; we can say the winter will be colder than the summer and we will get more rain," says O'Brien. "But what you really want to know is if it is going to rain on the day of your party." However, there are challenges replicating our ability to predict Earth weather in space.

Meteorologists utilise a vast network of monitors collecting data 24/7 as satellites constantly track weather systems from above in order to run their increasingly sophisticated simulations.

And while we have models of the solar wind and how it propagates through space and interacts with the Earth, we can't look down on the entire system as we can when tracking tropical storms or rain fronts.

"Imagine yourself as a meteorologist back in the pre-space age in the 1950s, and you are trying to make sense of all these spot measurements without the benefits of a satellite picture. That's probably where we are with space weather," says Scott.

Reliable space weather forecasts will also require a greater understanding of the relationship between what we see on the Sun's surface and what is in line to hit us several hours or days later. To help in this endeavour we have sent up a community of craft to monitor the Sun. However, they are all primarily scientific missions sent up to answer scientific questions. "They are proving useful, but they are not optimal," says Scott, whose STEREO mission can only provide data at the end of each day, which isn't much use when really powerful, fast-moving storms can get to Earth in 17 hours.

The scientific community are in regular contact with industry and space agencies who are working to ensure they have spares at the most

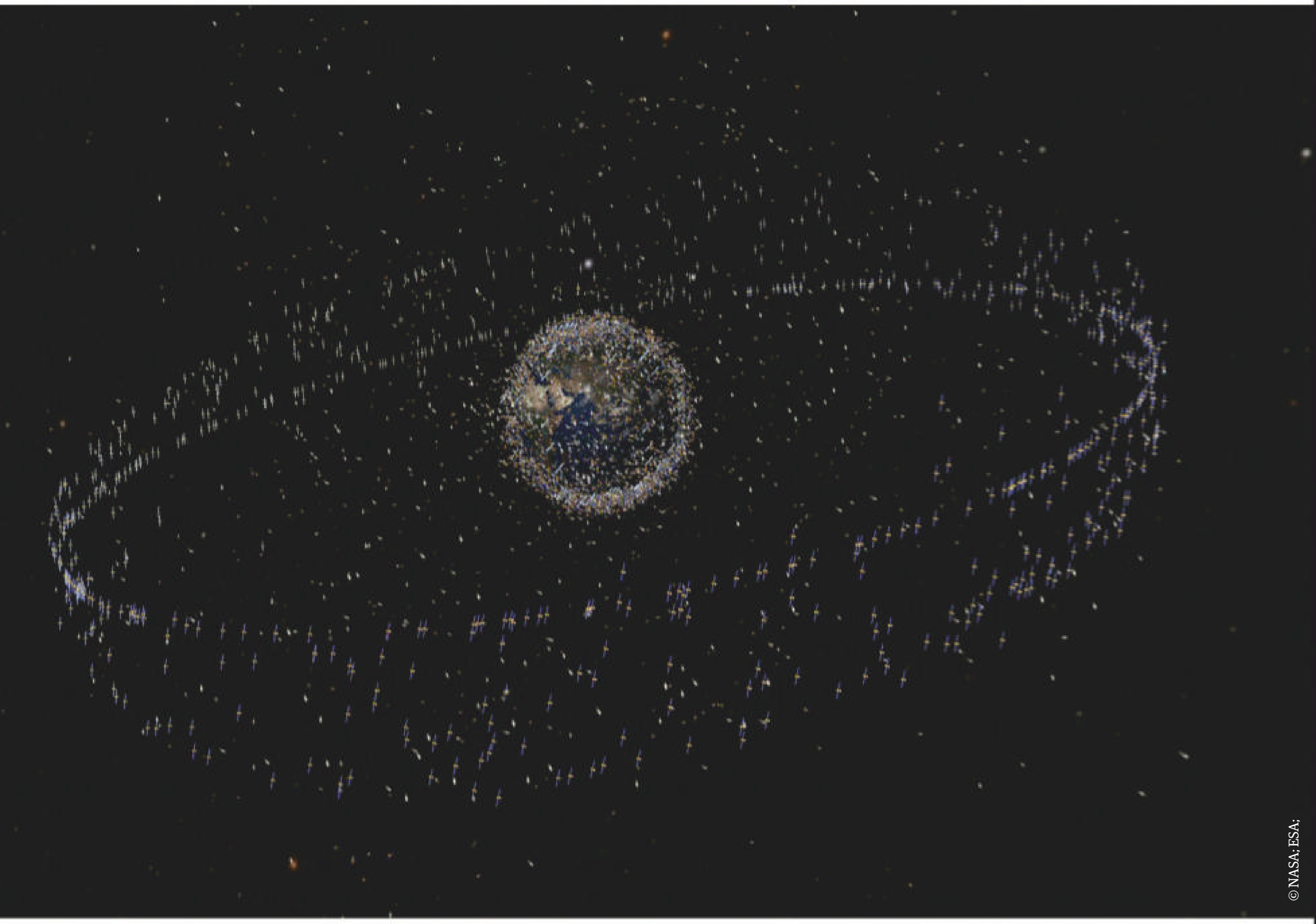
> "A lot of satellite operators choose not to worry about forecasts because they do not have sufficient accuracy" **Professor Chris Scott**

Clockwise, top left: A CME blasting from the Sun's surface in the direction of Earth

A massive sunspot around the size of Jupiter is identified by the SOHO spacecraft in 2003

Satellite operators have been warned of the dangers a large solar storm could pose

The Sun goes through a natural solar cycle every 11 years, composed of significant increases and decreases in sunspots and eruptions



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What if our Sun became too active?

With enough notice and preparedness we could negate the dangers and simply enjoy the greatest light show of all time

All eyes to the skies

If major solar activity were to threaten Earth, our solar science community and their legion of orbiters as well as land-based observatories would need to work out the likelihood, scale and arrival date of a direct hit.

Planes take the long way around

To avoid endangering staff and passengers with exposure to high radiation levels, operators of transatlantic flights would be encouraged to avoid usual 'over the poles' routes.

Astronauts take refuge

During an intense solar storm any planned spacewalks are cancelled and astronauts would be asked to set themselves up in the most shielded modules of the station.

Satellites switched to safe mode

If given sufficient notice of an incoming solar storm satellite operators would be encouraged to switch any orbiting units to safe mode.

Saving power

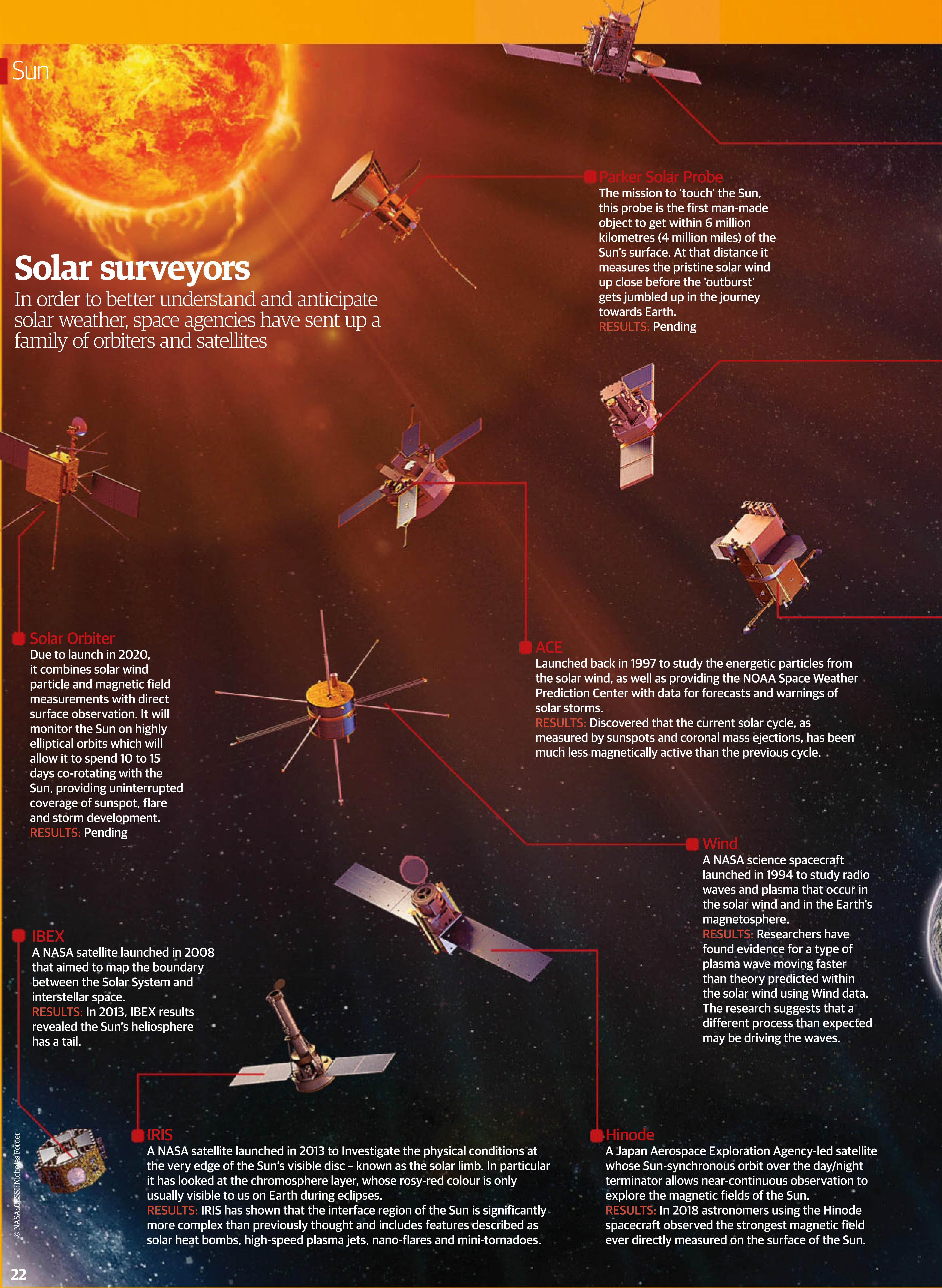
To avoid widespread blackouts power companies will need significant stocks of replacement transistors and crew deployed on the ground to tend to damaged parts of their grids

The greatest light show on Earth

One positive effect of intense solar activity is the chance for more people to enjoy the northern and southern lights at much lower latitudes than usual are bathed in aurorae.

Solar surveyors

In order to better understand and anticipate solar weather space agencies have sent up a family of orbiters, satellites and probes.



Solar surveyors

In order to better understand and anticipate solar weather, space agencies have sent up a family of orbiters and satellites

Parker Solar Probe

The mission to 'touch' the Sun, this probe is the first man-made object to get within 6 million kilometres (4 million miles) of the Sun's surface. At that distance it measures the pristine solar wind up close before the 'outburst' gets jumbled up in the journey towards Earth.

RESULTS: Pending

Solar Orbiter

Due to launch in 2020, it combines solar wind particle and magnetic field measurements with direct surface observation. It will monitor the Sun on highly elliptical orbits which will allow it to spend 10 to 15 days co-rotating with the Sun, providing uninterrupted coverage of sunspot, flare and storm development.

RESULTS: Pending

ACE

Launched back in 1997 to study the energetic particles from the solar wind, as well as providing the NOAA Space Weather Prediction Center with data for forecasts and warnings of solar storms.

RESULTS: Discovered that the current solar cycle, as measured by sunspots and coronal mass ejections, has been much less magnetically active than the previous cycle.

Wind

A NASA science spacecraft launched in 1994 to study radio waves and plasma that occur in the solar wind and in the Earth's magnetosphere.

RESULTS: Researchers have found evidence for a type of plasma wave moving faster than theory predicted within the solar wind using Wind data. The research suggests that a different process than expected may be driving the waves.

IBEX

A NASA satellite launched in 2008 that aimed to map the boundary between the Solar System and interstellar space.

RESULTS: In 2013, IBEX results revealed the Sun's heliosphere has a tail.

IRIS

A NASA satellite launched in 2013 to Investigate the physical conditions at the very edge of the Sun's visible disc – known as the solar limb. In particular it has looked at the chromosphere layer, whose rosy-red colour is only usually visible to us on Earth during eclipses.

RESULTS: IRIS has shown that the interface region of the Sun is significantly more complex than previously thought and includes features described as solar heat bombs, high-speed plasma jets, nano-flares and mini-tornadoes.

Hinode

A Japan Aerospace Exploration Agency-led satellite whose Sun-synchronous orbit over the day/night terminator allows near-continuous observation to explore the magnetic fields of the Sun.

RESULTS: In 2018 astronomers using the Hinode spacecraft observed the strongest magnetic field ever directly measured on the surface of the Sun.

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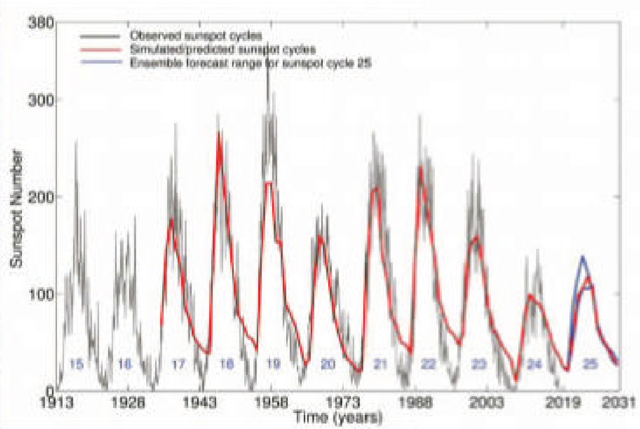


vulnerable parts of their grids, safe modes for their satellites, back-up routes for transatlantic airlines and safe houses for orbiting astronauts. However, today's rudimentary early warning systems make preparedness a significant economic risk.

"A lot of satellite operators choose not to worry about space weather forecasts because they do not have sufficient accuracy to make it worth their while," says Scott, who calls for a new observation-focused mission to put a spacecraft out far enough to see the Sun and the Earth in the same field of view. It would be stationed near enough to us to provide continuous real-time observations.

Further notice could be provided by looking for signature surface behaviour that proceeds major eruptions. This is where two of the latest additions to the Sun's community of human-made companions could prove useful. O'Brien's ESA-funded Solar Orbiter mission is due to launch in 2020. It combines solar wind particle and magnetic field measurements with direct surface observation, all from inside the orbit of Mercury.

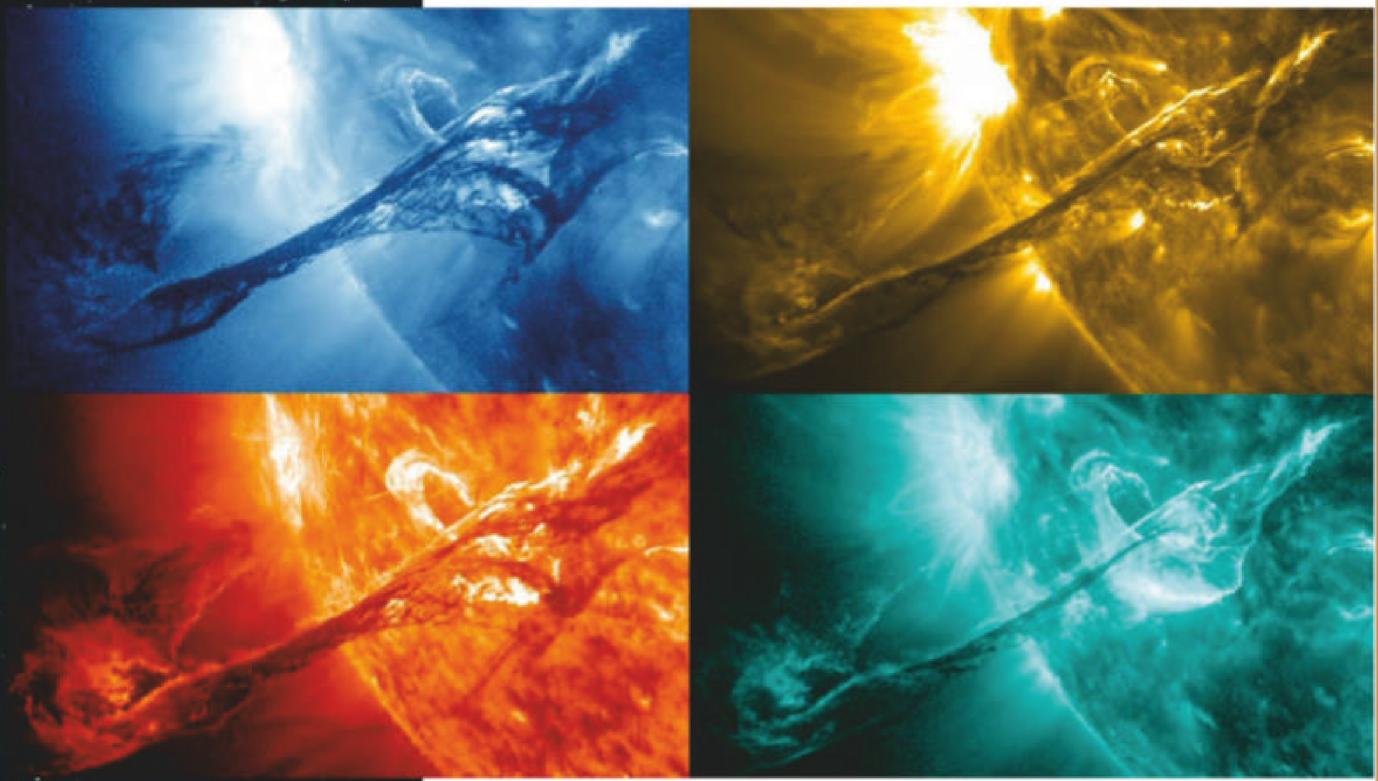
Key to the Solar Orbiter's ability to spot impending eruptions will be its highly elliptical orbit, which will allow it to spend 10 to 15 days co-rotating with the Sun, providing uninterrupted coverage of sunspot, flare and storm development.

While the Solar Orbiter will take direct solar observation closer than ever before, NASA's Parker Solar Probe is pushing the boundary yet further. On its journey to 'touch' the Sun the probe will eventually fly as close as 6.1 million kilometres (3.8 million miles), meaning it will pass through the Sun's outer atmosphere.

At that distance it hopes to measure the pristine solar wind – what it looks like when it leaves the Sun before it gets jumbled up in the 150-million-kilometre (93-million-mile) journey to Earth. "We will be able to couple together unprecedented details on what is happening on the dynamic, bubbling, boiling surface of the Sun with what is going in interstellar space," says O'Brien, who believes these new data sets and monitoring stations provide hope for our ability to give fair warning of future eruptions during the next solar cycle.

Above: Researchers have modelled the number of sunspots between 1913 and 2031

Below: The coronal mass ejection, viewed in four extreme ultraviolet wavelengths, in 2012 that sent a massive solar storm that just missed Earth

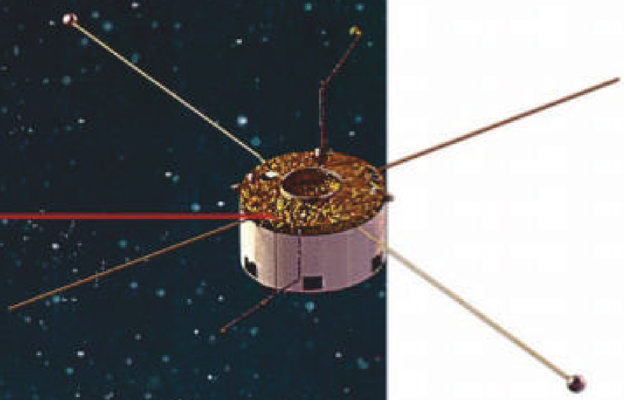


STEREO

Two near-identical spacecraft launched in 2006 into orbits around the Sun ahead of and behind the orbit of the Earth. This enables stereoscopic imaging to provide in-depth information when observing solar phenomena, such as coronal mass ejections.
RESULTS: One of the STEREO craft – STEREO A – was in the path of the solar storm of 2012 which was similar in strength to the Carrington Event. Its instrumentation was able to collect and relay a significant amount of data about the event.

SOHO

One of the original craft still in operation, SOHO was launched in 1995 and combines imagers and spectrometry instruments to probe the layered structure of the Sun with in-situ measurements of the solar wind as it goes past.
RESULTS: SOHO has also discovered over 3,400 comets as they orbit around the Sun, as well as providing the main source of near-real-time solar data for space weather prediction.



Solar Dynamics Observatory

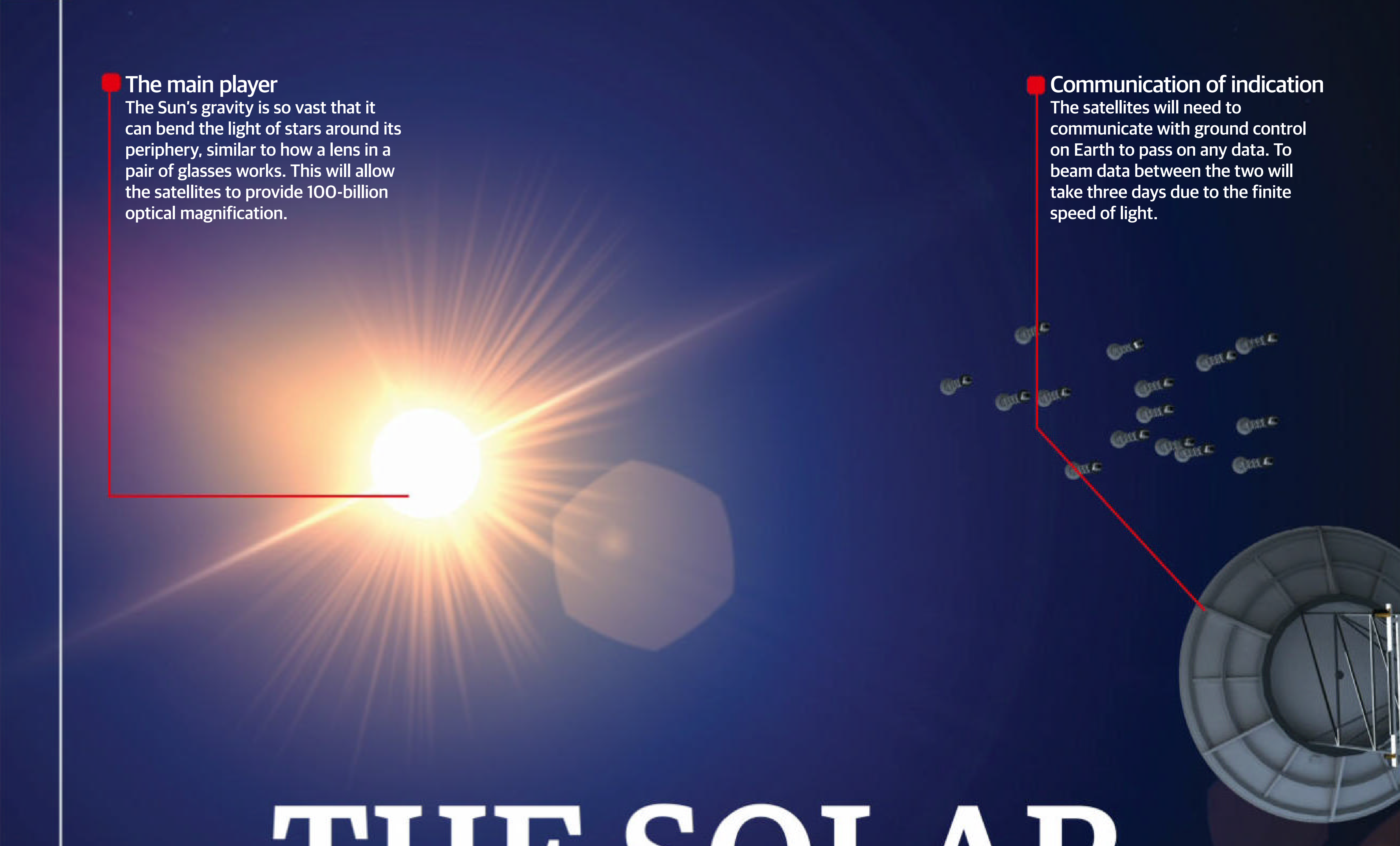
Launched in 2010 to investigate how the Sun's magnetic field is generated and structured and how this stored magnetic energy is converted and released into the heliosphere in the form of solar wind, energetic particles and variations in the solar irradiance.
RESULTS: Has identified possible precursors to space weather in the behaviour of plasma within the regions encircling sunspots.

Cluster II

Launched in 2000, the Cluster II mission is an in-situ investigation of the interaction between the solar wind and the magnetosphere by using four satellites.
RESULTS: Has developed the first models of the Earth's magnetic field and its interaction with the solar wind based on actual measurements rather than theory.

DSCOVR

Originally proposed by then-Vice President Al Gore, DSCOVR monitors variable solar wind conditions and their impact on the Earth, including changes in ozone, aerosols, dust and volcanic ash, cloud height, vegetation cover and climate.
RESULTS: Took the second picture of the entire Earth, following on from the final Apollo mission's famous Blue Marble picture.



The main player
The Sun's gravity is so vast that it can bend the light of stars around its periphery, similar to how a lens in a pair of glasses works. This will allow the satellites to provide 100-billion optical magnification.

Communication of indication
The satellites will need to communicate with ground control on Earth to pass on any data. To beam data between the two will take three days due to the finite speed of light.

THE SOLAR GRAVITY LENS

A swarm of telescopes placed billions of kilometres away will be able to reveal a universe full of exoplanets

The search for exoplanets is a relatively new and exciting aspect of study, and finding Earth 2.0 is a goal that astronomers hope to achieve by using innovative methods of detection. Based on Einstein's theory of general relativity which predicted that the most massive objects in universe can warp the space around them and can bend light, a process known as gravitational lensing, it is possible to concentrate distant light to allow for a closer look.

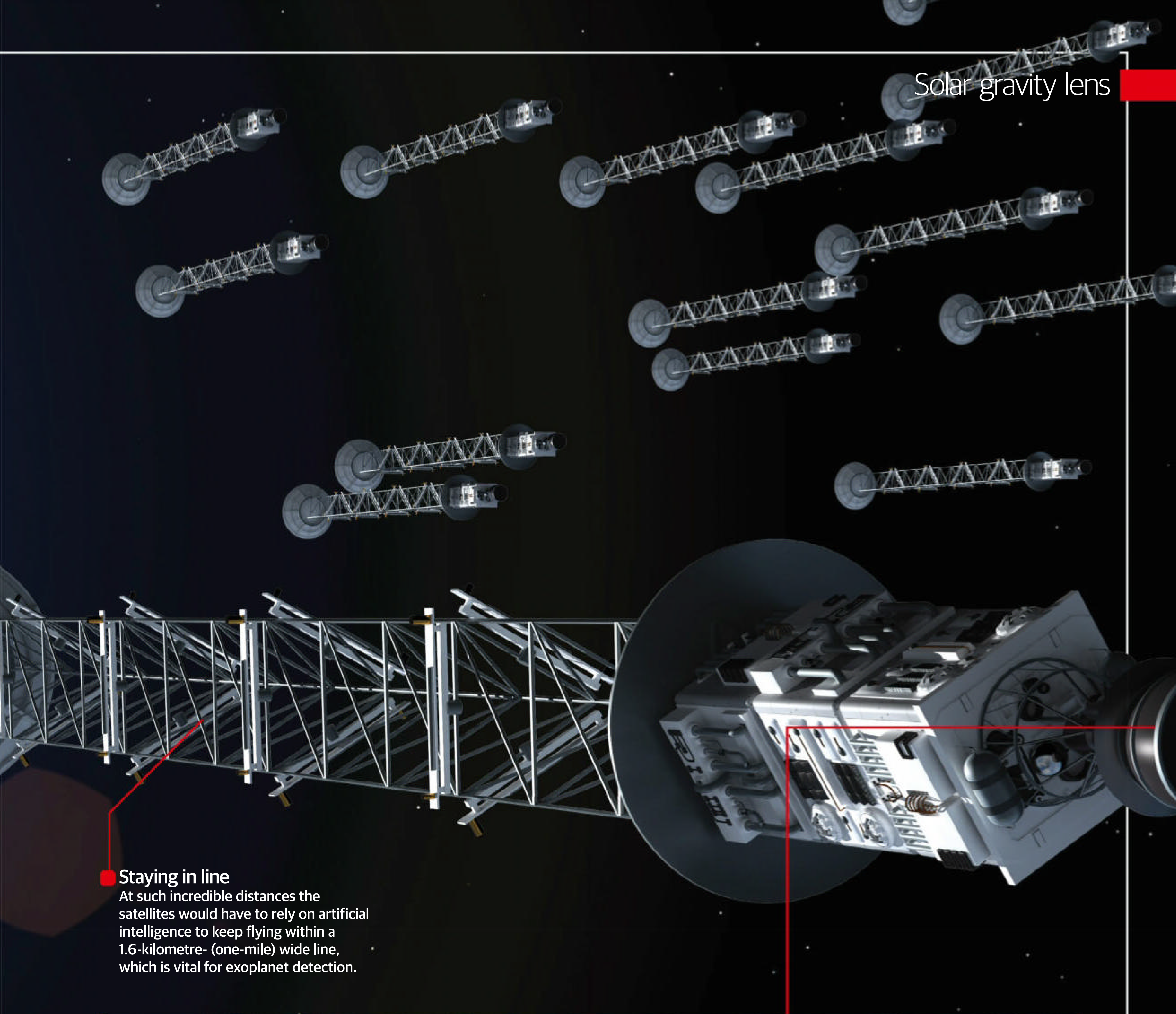
This century-old theory has led to the development of the solar gravity lens (SGL) method of exoplanet detection, courtesy of scientists from NASA's Jet Propulsion Laboratory and The Aerospace Corporation. This two-year study was made possible when Aerospace was awarded a $130,000 contract from JPL as part of the NASA Innovative Advanced Concepts (NIAC) Phase II program.

"SGL requires placement of an array of detectors that observe the light from exoplanets once they arrive at a distance approximately 50 billion miles [80.5 billion kilometres] or 550 astronomical units (AU) from Earth," says Tom Heinsheimer, Aerospace's technical co-lead for SGL. "To get to that solar gravity line the swarm of spacecraft will need to use a solar sail to fly out of the Solar System at a velocity of over 75 miles [121 kilometres] per second." One AU is the Earth-Sun distance, meaning the distance of this focal 'ring' would be three light days away.

By placing a system of telescopes over 80 billion kilometres (50 billion miles) from Earth the SGL will provide an outstanding magnification of 100 billion. This level of magnification will reveal details as small as 10-kilometres (six-miles) across – the equivalent of spotting New York City on an exoplanet. This grand scale of telescopes would undeniably tackle exoplanet detection in a pioneering fashion, but there are problems to tackle before doing so – the main one being having to send a swarm of satellites such an enormous distance from Earth.

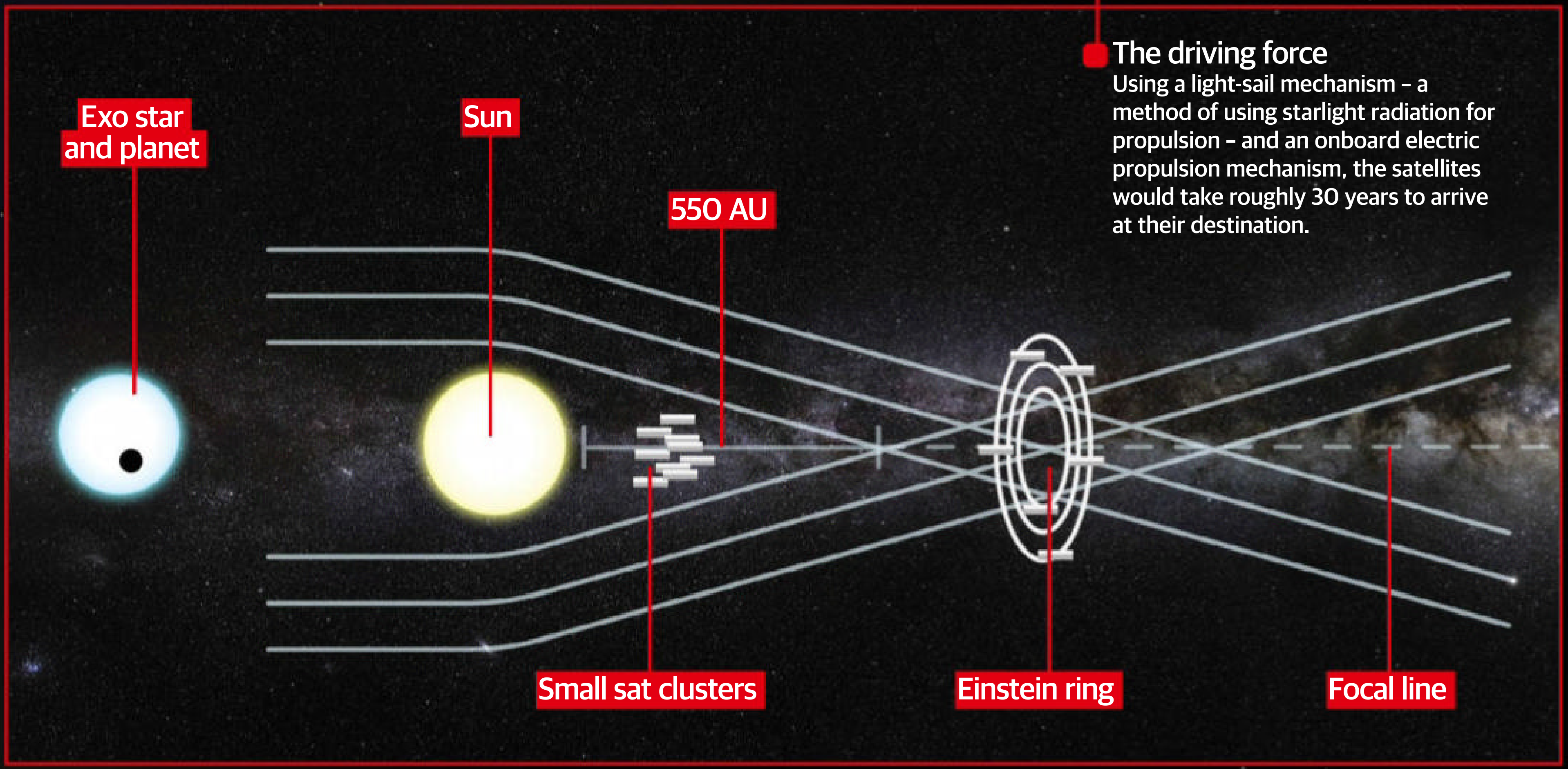
When considering the farthest human-made object, NASA's Voyager 1 currently holds that record at 145 AU from Earth – and that has taken over 40 years! This long time span is only because the spacecraft was restricted by the technologies of its time. With the new proposed propulsion and light-sail concept the cluster of small telescopes will take roughly 30 years to get to a distance of 550 AU.

The navigation and propulsion will require some form of artificial intelligence, as technologies will need to keep the spacecraft flying in a 1.6-kilometre- (one-mile) wide line that will contain the light from the exoplanet. As this round trip of communication with Earth would take six days it is imperative that this swarm can adapt and learn from experience.



Staying in line
At such incredible distances the satellites would have to rely on artificial intelligence to keep flying within a 1.6-kilometre- (one-mile) wide line, which is vital for exoplanet detection.

The driving force
Using a light-sail mechanism – a method of using starlight radiation for propulsion – and an onboard electric propulsion mechanism, the satellites would take roughly 30 years to arrive at their destination.



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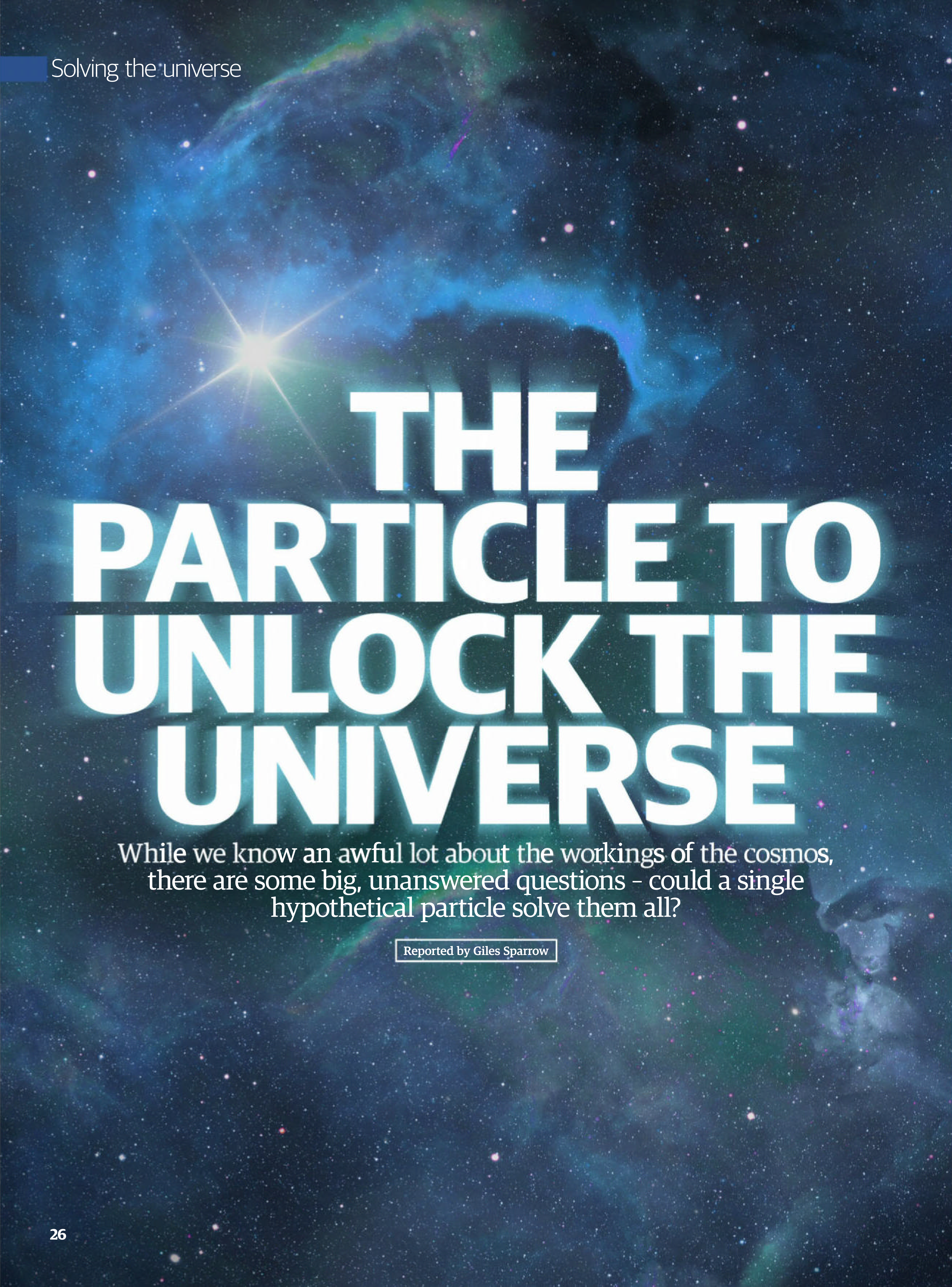


THE PARTICLE TO UNLOCK THE UNIVERSE

While we know an awful lot about the workings of the cosmos, there are some big, unanswered questions – could a single hypothetical particle solve them all?

Reported by Giles Sparrow

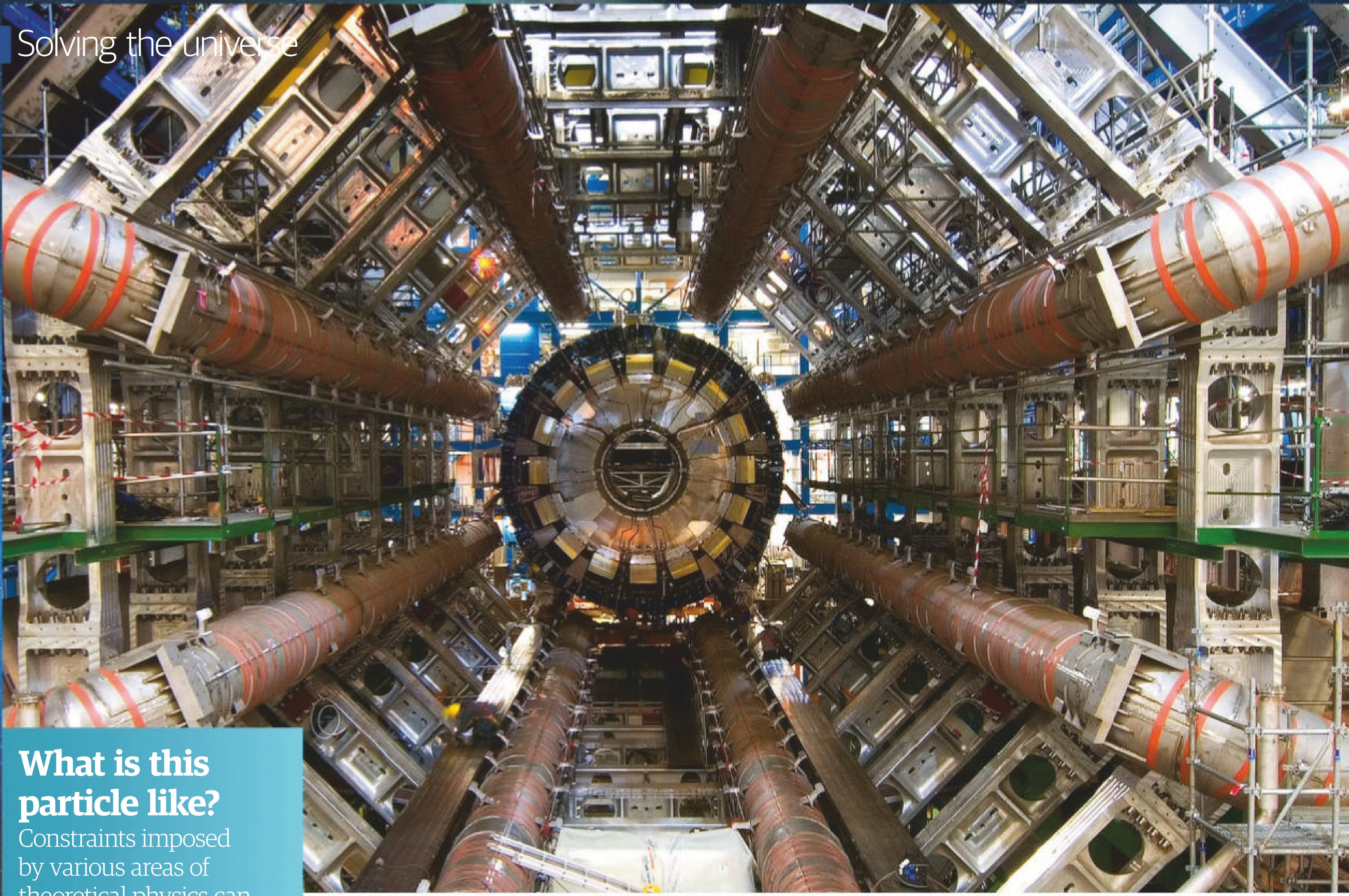
Cosmology and particle physics are arguably two of the most mind-boggling fields in all of science, seeking to explain the fundamental workings of our universe on very different scales. So far, the 21st century has seen huge advances in both these allied quests, with cosmologists confirming the existence of dark energy and making further advances in the understanding of mysterious dark matter. Meanwhile, particle physicists have pieced together the missing pieces of the 'Standard Model', a long-standing theory explaining the structure of the matter that makes up our visible universe.

But there are still some big questions left for scientists in both fields. For cosmologists, one of the biggest puzzles is the nature of dark matter - we may now understand many of its properties and behaviours, but we still don't know what it is. Another question surrounds the driving force behind inflation - the sudden expansion of the newborn universe in the first microsecond after the Big Bang.

Meanwhile, particle physicists wrestle with annoying loose ends at the fringes of the Standard Model. Why do the six distinct quarks - particles that bind together to create more familiar particles such as protons and neutrons - have wildly different masses? How does the famous Higgs boson - associated with the process that gives other particles their mass - originate, and why does this particle display less than 100 million-billionth of the mass and energy predicted by theory?

Is it possible that a single new theory could resolve all these annoying questions and perhaps provide a way of finally uniting the physics of the smallest and largest scales? That's the remarkable possibility emerging from recent theoretical breakthroughs at theoretical hubs such as the Max Planck Institute (MPI) for Nuclear Physics in Heidelberg, Germany. And while various theories proposed to 'patch' the Standard Model so far have called for anything from half a dozen new particles to an entire supersymmetric mirror-universe of undiscovered stuff, the new theory relies on just a single new subatomic particle. Different researchers have proposed various names for this elusive particle, but so far the 'axiflavon' seems to have gained most traction.

This curious name combines those of two other hypothetical particles of longer standing - the 'axion' and the 'flavon'. Both proposed independently as long ago as the 1970s, each aimed at solving its own distinct problem in the Standard Model.



Above: If the axiflavon exists and has a relatively strong coupling to photons, then normal stars could lose mass by generating them through their lifetime.

What is this particle like?

Constraints imposed by various areas of theoretical physics can help scientists pin down the axiflavon

Lightweight particle

The axiflavon's mass must lie between one 100th and one 10 billionth of an electronVolt. For comparison, the mass of an individual electron is about 500,000 electronVolts.

Coupling with light

The axiflavon's photon coupling – the strength of its effects on radiation, including light – is very weak, but increases if it has a higher mass.

Gamma-ray signal?

The axiflavon's weak effect on electromagnetic radiation might still be enough to detect a pattern in the energies of cosmic gamma rays.

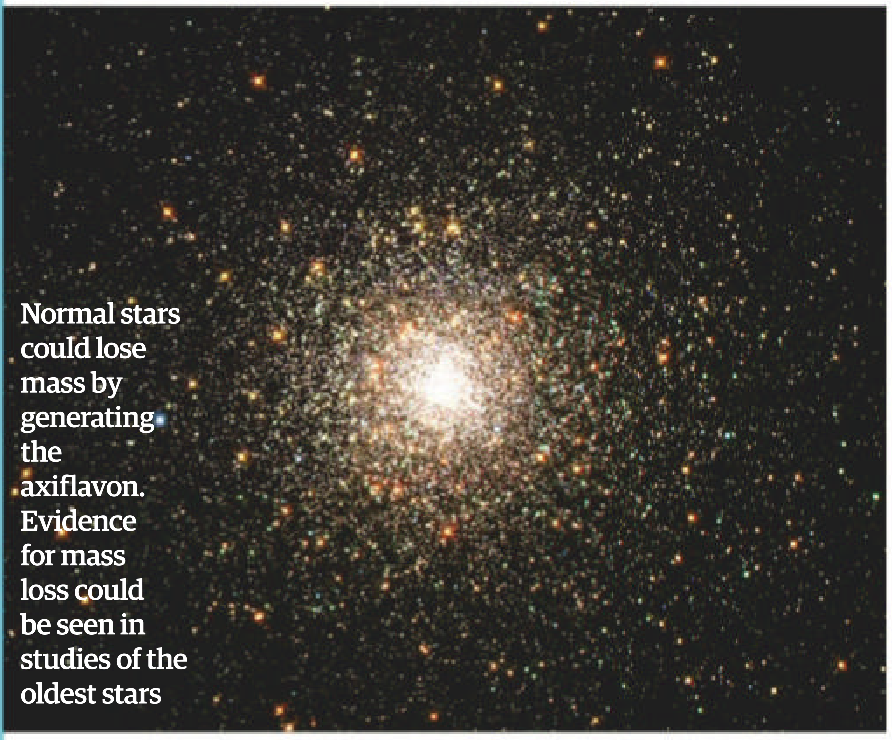
Axiflavon sources

Depending on their mass, axiflavons could be steadily released from the cores of normal stars, or only forged in the explosive hearts of supernovae.

Plain particle

In order to behave in the ways required the axiflavon should have no electric charge, and also a particle spin of zero.

Flavons, to put it as simply as possible, are associated with the 'flavon field', a hypothetical force field affecting quark particles that make up the protons and neutrons in the cores of atoms. Quarks come in six different flavours, but can sometimes change from one flavour to another using the so-called weak interaction, one of nature's four known fundamental forces; this is how atoms change their identity in certain forms of radioactive decay. In order to explain how the different quark flavours display wildly different masses, physicists suggested another layer of complexity on top of the Standard Model - a 'flavon field' that linked quarks with the mass-producing Higgs boson. Interactions in this new field would be carried by a new 'messenger particle' known simply as the flavon.



Normal stars could lose mass by generating the axiflavon. Evidence for mass loss could be seen in studies of the oldest stars

At around the same time, other physicists were puzzled over a problem with the 'strong interaction', an even more powerful nuclear force that binds particles together in the atomic nucleus. Known as the 'strong CP' problem, the issue was just why certain strong-force interactions are symmetric when the Standard Model suggests that they shouldn't be.

According to the Standard Model the strong interaction is expected to break so-called 'CP' or 'charge-parity' symmetry - a rule that interactions will look the same if the electric charges of the particles involved are reversed, while their spatial coordinates are also flipped. The fact that the strong interaction does not break symmetry in this way led physicists Roberto Peccei and Helen Quinn at Stanford University to hypothesise another set of unseen interactions taking place at the tiniest scales involving a previously undetected force field keeping things in line. Princeton physicist Frank Wilczek extended the theory by suggesting that the force field should have an associated particle, for which he coined the name 'axion'.

At first glance the axion and flavon seem to have little in common, but the world of nuclear physics is strange, and particles and forces that seem very different in everyday circumstances can reveal unexpected similarities at high temperatures and energies, such as those that occurred in the Big Bang itself. By colliding particles at close to the speed of light in accelerators such as the Large Hadron Collider (LHC), physicists have found

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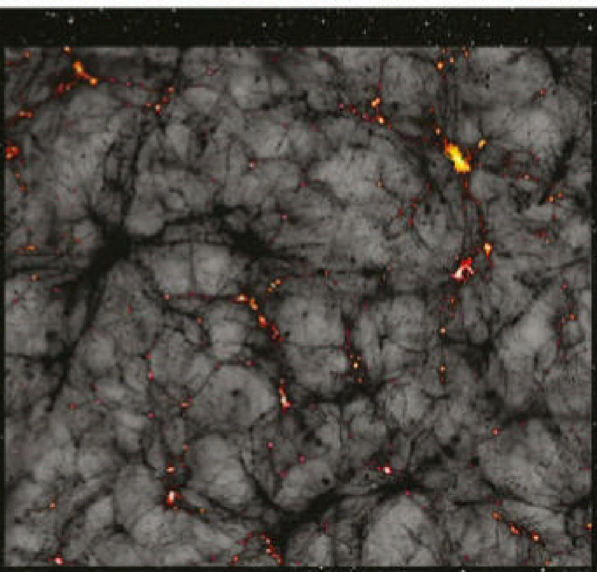
THE 5 MYSTERIES THE PARTICLE COULD SOLVE

Though hypothetical, the axiflavon promises to solve five of the biggest mysteries in modern physics and cosmology

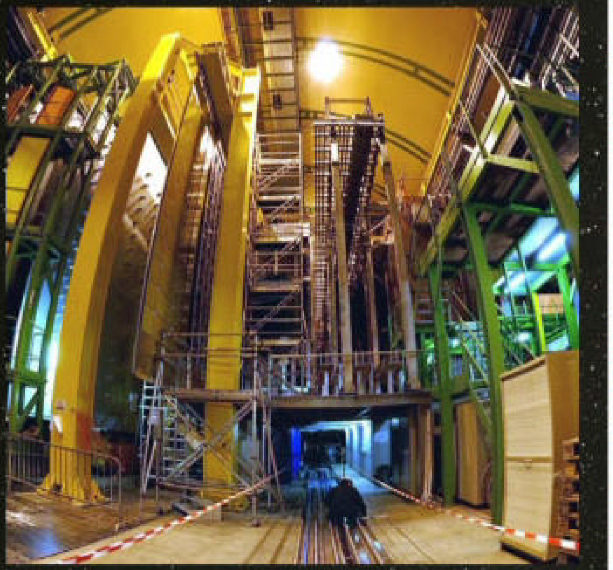


What is dark matter?

All of the universe's visible material, from stars and galaxies to interstellar gas and dust clouds, accounts for just one-sixth of its overall mass – the rest, revealed only through the influence of its gravity, is not just dark, but invisible and transparent. Evidence suggests that dark matter consists of unknown particles that cluster loosely around concentrations of visible matter such as galaxies – axiflavons, if their existence is proven, could have just the properties required for a dark matter candidate.

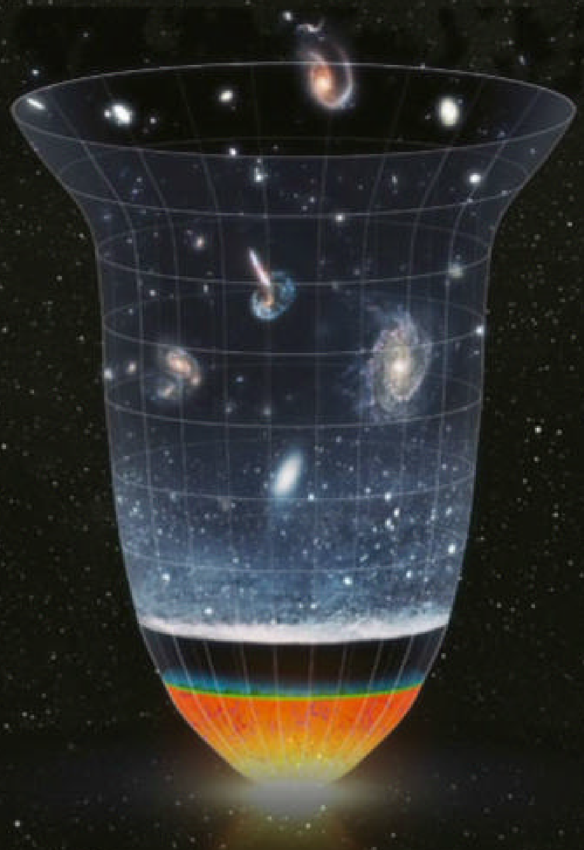
The 'reversed' universe

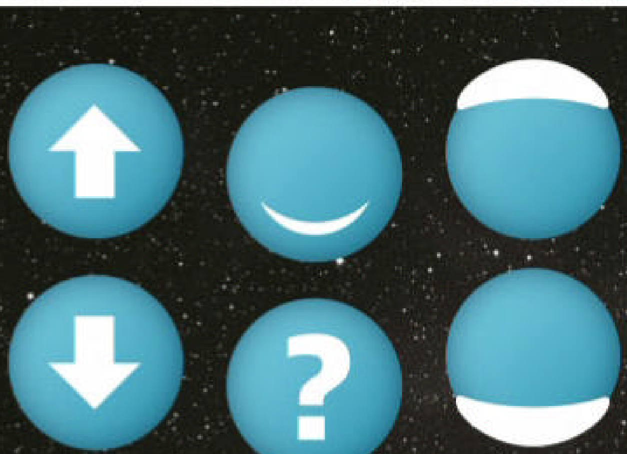
For physicists, symmetry is the question of whether a process or interaction is symmetric and involves looking at how it behaves when certain properties are reversed. The axion field and particle were invented to explain why strong-force interactions, against expectation, maintain charge-parity symmetry. Confirmation of an axiflavon capable of displaying axion-like properties in certain situations would resolve the strong CP problem for once and for all.



The cause of inflation

The modern Big Bang theory requires inflation – a burst of sudden expansion just after the moment of creation in order to 'smooth out' the raw material of the universe and give rise to the distribution of matter we see today – but how did inflation work? One theory involves a hypothetical 'inflation field', giving rise to inflation particles whose properties could also match those of the axiflavon. As inflation came to an end and the universe continued to cool, these particles decayed in the lower energy conditions to produce today's matter particles.



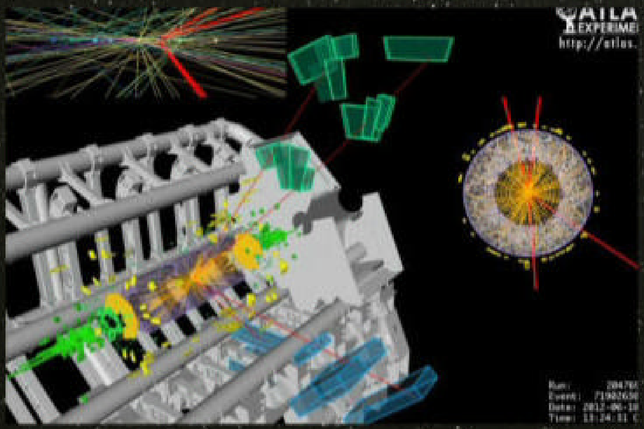


The quark flavour problem

Quark particles come in six distinct 'flavours' – the common up and down quarks found in everyday matter, and the exotic strange, charm, top and bottom quarks. In theory quarks should be able to change flavour through the weak interaction, but the huge differences between different flavours complicate the question. The hypothetical flavon field resolves the problem using namesake particles to give the quarks different amounts of 'drag' through the mass-producing Higgs field. Axiflavons are ideal particles for controlling these interactions.

The Higgs boson mass mystery

First proposed in 1964 and discovered at the Large Hadron Collider in 2012, the Higgs boson confirms the existence of the mass-producing Higgs field and completes the Standard Model of particle physics. But why does this particle apparently weigh so much less than it should? Axiflavon-Higgs unification suggests that the mystery could be explained if the Higgs is just one aspect of a multi-purpose particle.

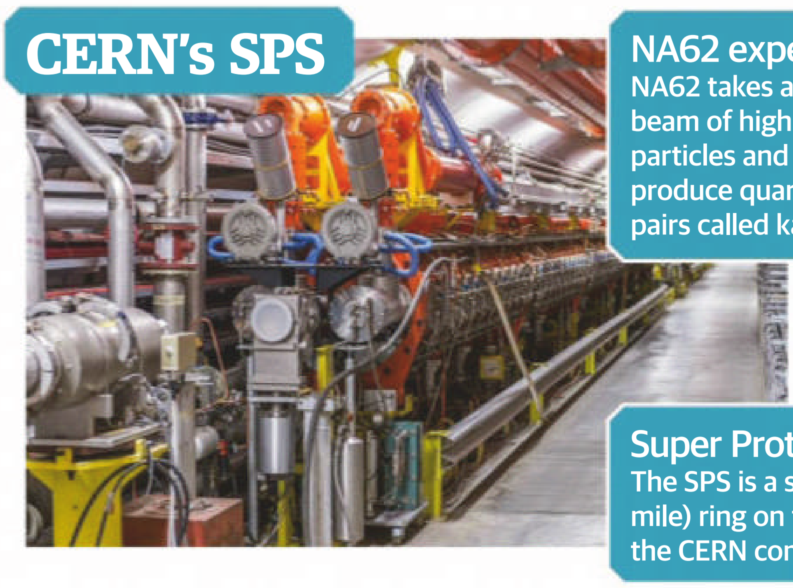


> "We found that the flavon and the axion could be realised together as two components of a single 'complex' scalar field" **Dr Florian Goertz**

On the hunt through a particle smasher

While the huge detectors of the Large Hadron Collider have helped to constrain the axiflavon's potential properties, proof of its existence may emerge from a slightly more modest experiment

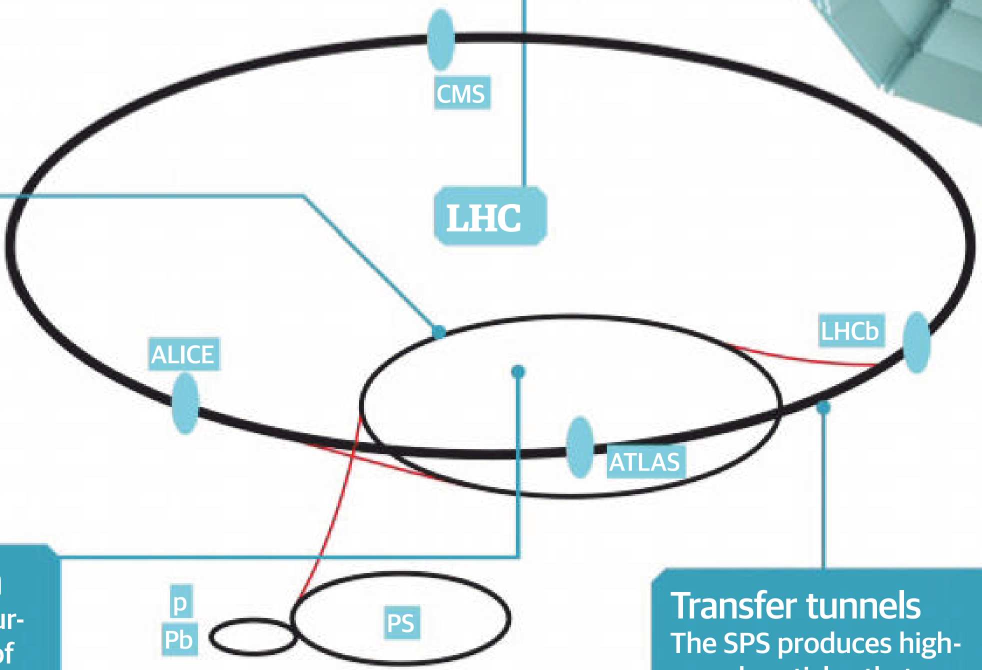
CERN's SPS



NA62 experiment
NA62 takes a separate beam of high-speed particles and uses them to produce quark/antiquark pairs called kaons.

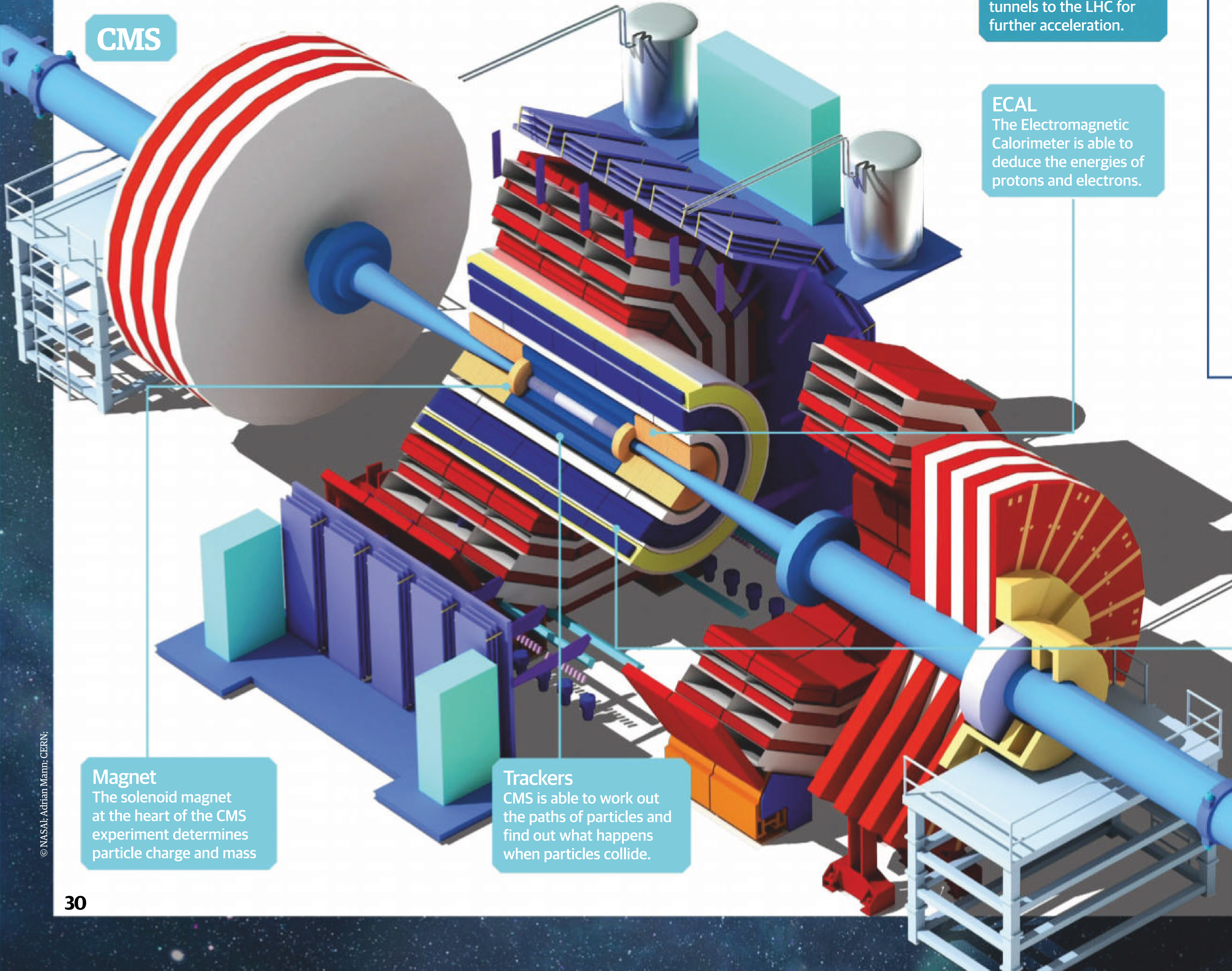
Super Proton Synchrotron
The SPS is a seven-kilometre (four-mile) ring on the northern edge of the CERN complex.

Large Hadron Collider
CERN's famous LHC is a huge ring with a 27-kilometre (16.7-mile) circumference deep beneath the Franco-Swiss border.



Transfer tunnels
The SPS produces high-speed particles that are then fed through these tunnels to the LHC for further acceleration.

CMS



ECAL
The Electromagnetic Calorimeter is able to deduce the energies of protons and electrons.

Magnet
The solenoid magnet at the heart of the CMS experiment determines particle charge and mass

Trackers
CMS is able to work out the paths of particles and find out what happens when particles collide.

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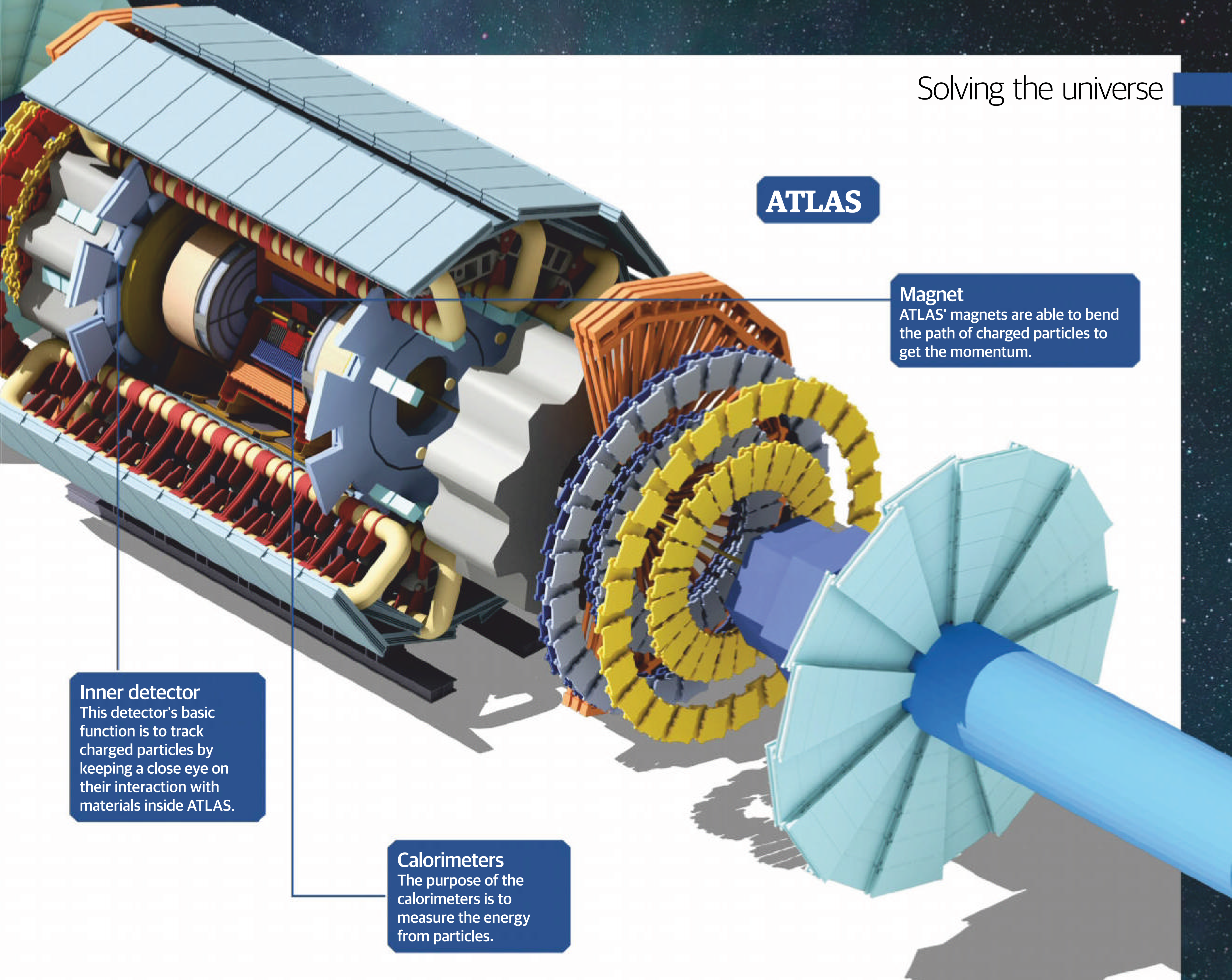

ATLAS
Magnet
ATLAS' magnets are able to bend the path of charged particles to get the momentum.
Inner detector
This detector's basic function is to track charged particles by keeping a close eye on their interaction with materials inside ATLAS.
Calorimeters
The purpose of the calorimeters is to measure the energy from particles.
Spectrometer
ATLAS owns a spectrometer that allows it to work out the momentum of muons.
HCAL
The Hadron Calorimeter works out the energy of hadrons, particles made of quarks and gluons.

evidence of electromagnetism and the weak interaction behaving as a single 'electroweak' force. In fact, most physicists believe that all four fundamental forces - electromagnetism, the weak and strong interactions and gravity - were unified in the instant of the Big Bang itself before rapidly separating in the era of cosmic inflation.

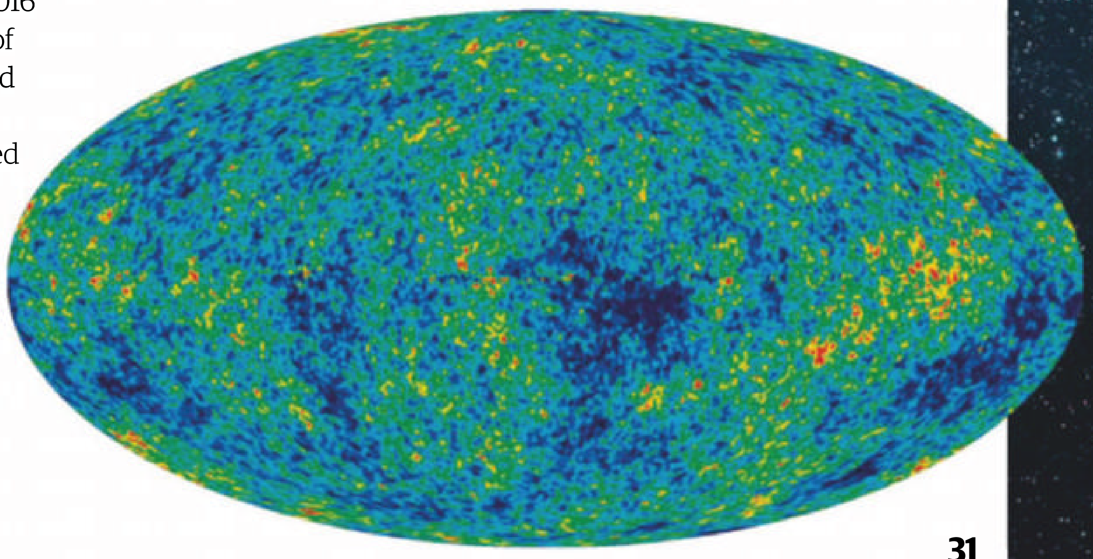
If this hypothesis is correct then the electroweak and strong interactions are close cousins, and the idea of a similar link between the flavon and the axion shouldn't seem so far-fetched - could they indeed be different present-day manifestations of a single particle, the axiflavon?

That's the idea now being proposed by a number of physicists. A key breakthrough came in late-2016 when Lorenzo Calibbi of the Chinese Academy of Sciences in Beijing, Florian Goertz of the MPI and others around the world published a number of papers investigating it. Calibbi and Goertz pointed out how one component of the proposed flavon field has properties that match those expected of the axion. "We found that the flavon and the axion could be realised together as two components of a single 'complex' scalar field," explains Goertz. Put simply, a scalar field is one that is defined by a single number, effectively its strength, at any point in space.

Of course, there's no shortage of hypothetical ideas at the speculative end of theoretical physics, but Calibbi and Goertz's idea caught the imagination of physicists around the world more than most, for reasons Goertz explains: "This [axiflavon hypothesis] very economically solves some major problems in physics such as the flavour puzzle, strong CP problem and dark matter. It also leads to a very predictive set-up since, for example, the axion now inherits properties from the flavon."

In a nutshell, that means that a combined axiflavon has the potential to solve other big problems in 21st-century physics, beyond the issues of quark mass and strong CP. Cosmologists

Below: The distribution of matter seen in the CMB echoes the structure of today's galaxy superclusters - but an early burst of cosmic inflation is needed to produce such a pattern



have for some time considered the axion as a possible source of dark matter and an identity for the 'inflaton'. An axiflavon could work equally well to solve both problems.

Another problem that the axiflavon might solve is the deeper nature of the Higgs boson itself. "In an article published in July, Tommi Alanne, Simone Blasi and I studied whether the axiflavon scalar could be part of a bigger scalar multiplet - that is, a 'larger' unified field containing further particles - that also includes the Higgs field, the source of elementary-particle masses," Goertz explains.

In other words, it seems that it's possible that the Higgs and the axiflavon can themselves be unified into a particle that exhibits the properties of both axion, flavon and Higgs in different situations. Although the work done so far does not offer a direct explanation for the unexpectedly low mass of the Higgs found in real-world experiments, further research could offer new insights into this puzzle.

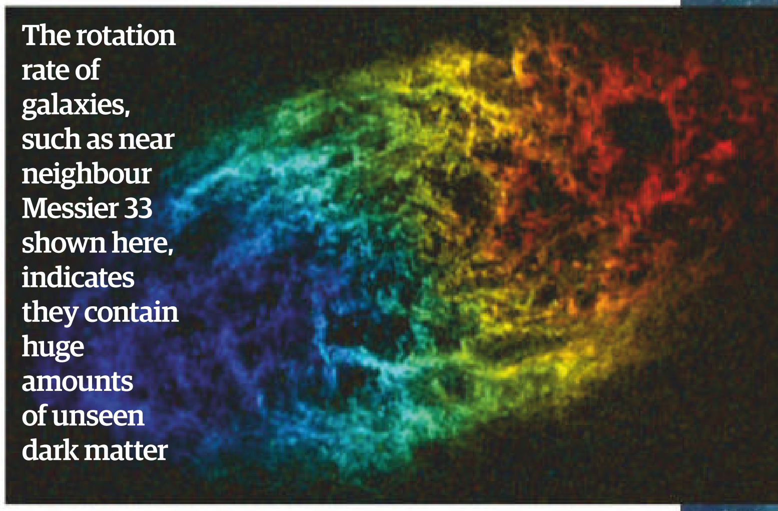
Unsurprisingly, physicists are finding the idea of the axiflavon immensely alluring - not only does it solve some major outstanding problems, but a single particle manifesting appeals to hopes for a fundamental simplicity in nature, rather than muddying the waters with countless hypothetical particles and fields to do different jobs.

Aside from this, as Goertz hints above, the theory is predictive - if it's correct it says certain things about the way subatomic particles behave that can be tested using current technology.

"[Because] the axion now inherits properties from the flavon, it's possible to search for it using flavour experiments," Goertz continues. "In fact, one of the best hopes to find the axiflavon is the existing NA62 experiment at CERN [the European Organisation for Nuclear Research on the Swiss/French border]."

NA62 is one of CERN's less glamorous experiments, and even its name is simply code for North Area 62. While the huge cavern-filling detectors of the 27-kilometre- (16.7-mile) long Large Hadron Collider ring get most of the attention, the complex also incorporates a seven-kilometre (four-mile) ring on its northern side called the Super Proton Synchrotron (SPS). This smaller particle accelerator generates collisions using a powerful beam of positively charged protons and other particles travelling at close to the speed of light, and NA62 is using this beam to study the decay of quark/antiquark pairs called kaons - an antiquark is an 'antimatter' quark with the opposite electric charge to its 'normal' counterpart. After several years of trials the experiment began a two-year run to collect data in earnest in 2016.

"NA62 is searching for the decay of a kaon to a pion and 'invisible' particles leaving the detector," explains Goertz. "In the Standard Model of particle physics these particles are the neutrinos. However, if the axiflavon exists it would lead to a similar signal, and thus be detected as an enhancement in the data."

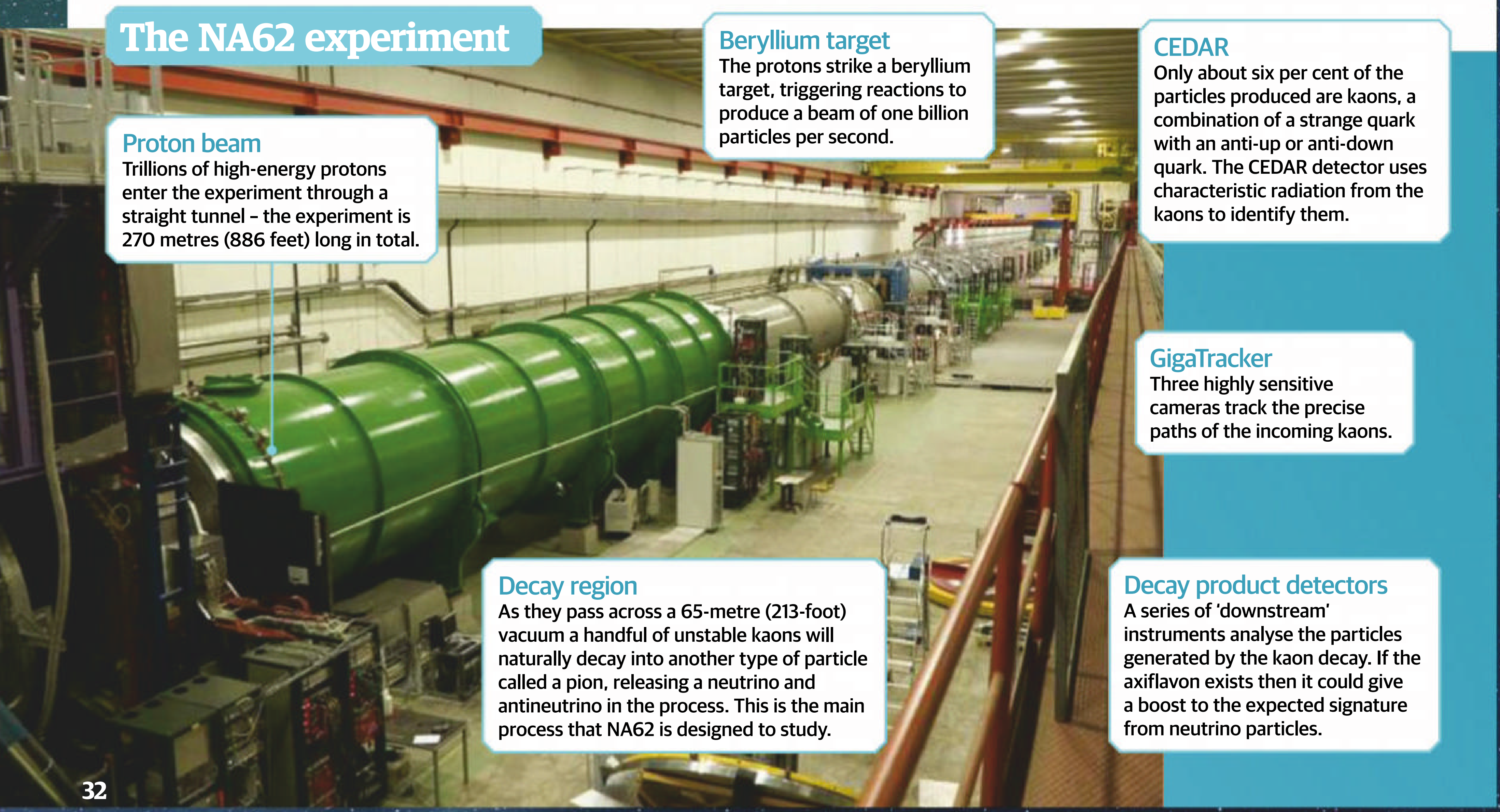

The rotation rate of galaxies, such as near neighbour Messier 33 shown here, indicates they contain huge amounts of unseen dark matter

NA62's observations of these rare decay events - so rare that the experiment is predicted to only observe 80 in each two-year run - could at least hint at the axiflavon's existence, as could the Belle II experiment at the SuperKEKB accelerator in Japan. But, with the new model adding Higgs unification to the mix, Goertz hopes to be even more conclusive: "The possible unification with the Higgs [makes] the model even more predictive, such that at the NA62 experiment we could basically fully disprove it, if it exists."

If Goertz and his colleagues are right then the next couple of years could see a new discovery to rival the Higgs boson itself, and finally wrap up some of our biggest remaining mysteries about the universe. But, sadly, for the moment we shall just have to wait!

> "It seems possible that the Higgs and the axiflavon themselves can be unified into a particle that exhibits the properties of both axion, flavon and Higgs in different situations"

The NA62 experiment



Proton beam
Trillions of high-energy protons enter the experiment through a straight tunnel – the experiment is 270 metres (886 feet) long in total.

Beryllium target
The protons strike a beryllium target, triggering reactions to produce a beam of one billion particles per second.

CEDAR
Only about six per cent of the particles produced are kaons, a combination of a strange quark with an anti-up or anti-down quark. The CEDAR detector uses characteristic radiation from the kaons to identify them.

GigaTracker
Three highly sensitive cameras track the precise paths of the incoming kaons.

Decay region
As they pass across a 65-metre (213-foot) vacuum a handful of unstable kaons will naturally decay into another type of particle called a pion, releasing a neutrino and antineutrino in the process. This is the main process that NA62 is designed to study.

Decay product detectors
A series of 'downstream' instruments analyse the particles generated by the kaon decay. If the axiflavon exists then it could give a boost to the expected signature from neutrino particles.

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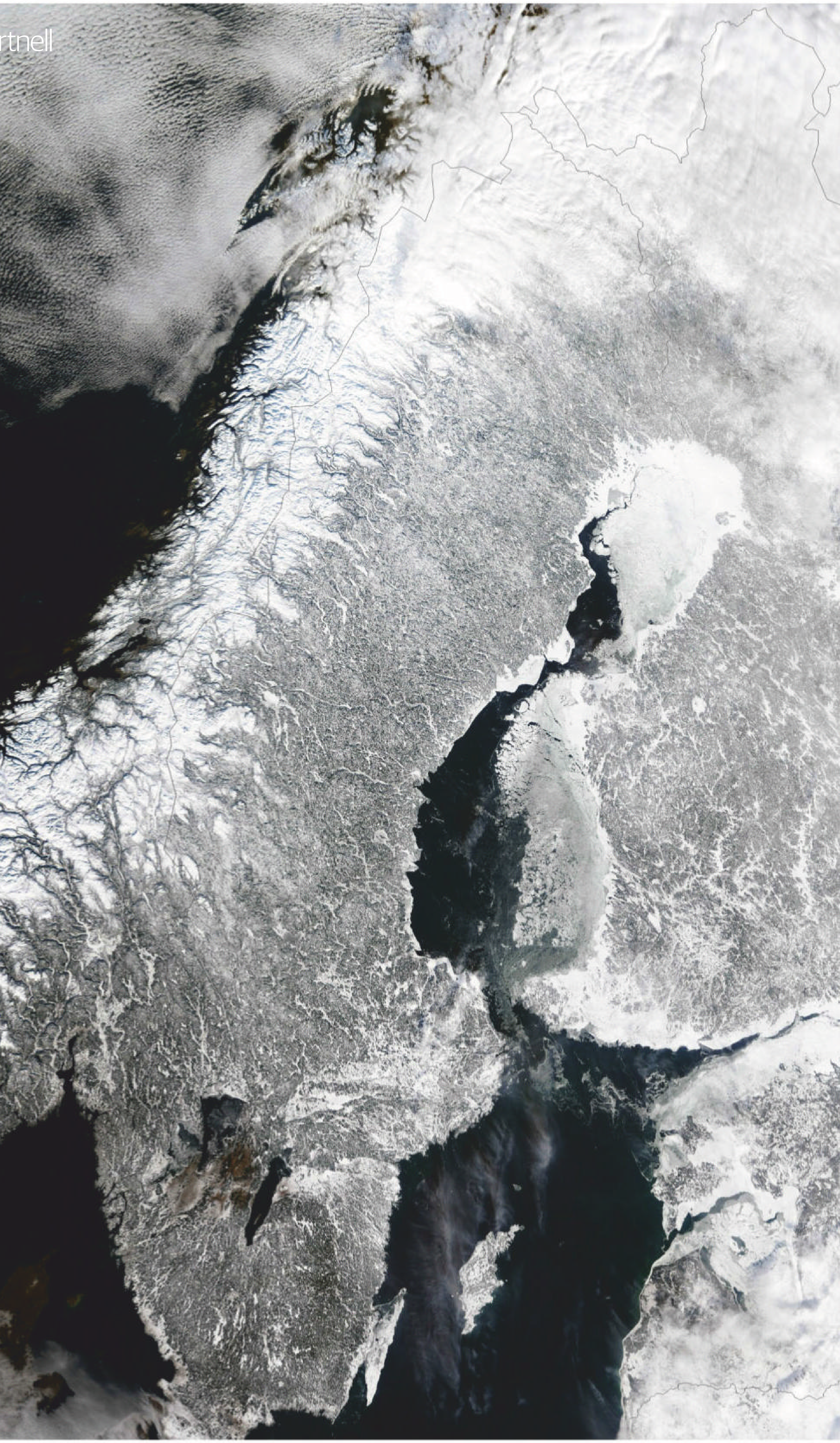
INTERVIEW BIO

Professor Lewis Dartnell

Lewis Dartnell is a British astrobiologist and the professor of Science Communication at the University of Westminster, London. His research primarily focuses on microbial life and how that might survive or be detected on the surface of Mars.

Dartnell is also an author, with his last *Sunday Times* bestseller *The Knowledge*, being so successful he has released another book titled *Origins: How the Earth Made Us*. This new book moulds history and science and tells the story of not only how we changed the Earth, but how the Earth helped make us.



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A GLIMPSE INTO THE PLANET THAT EVOLVED WITH US

Professor Lewis Dartnell talks fusing history with science and looking back on how civilisations, the Ice Age and even our origins have all been undeniably influenced by this ball of rock and water we call Earth

Reported by Lee Cavendish

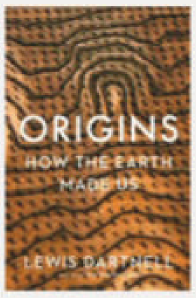
What was your inspiration for writing *Origins*?
With all of my books I've written the book I wanted to read but realised didn't exist yet. It was something that I was really interested in and curious about and I wanted to find out. I took this opportunity to just go off and dig around the subject, do a whole load of research and reading and condense that down to a book for other people.

For my last book, *The Knowledge*, that all came out of a very simple thought experiment about what would you do to reboot civilisation after an apocalypse. The book has nothing to do with the end of the world; it's just a way of asking that question of where stuff comes from in our everyday life and how can you recover it all if you wanted to.

What I wanted to do with the new book, *Origins*, is have an even grander canvas to paint with. Even more so than the history of science and technology, but also look into the history of us as a species and our planet and how those two things have interacted with each other. So it's a lot of history, a lot of science and a lot of space stuff coming into that as well.

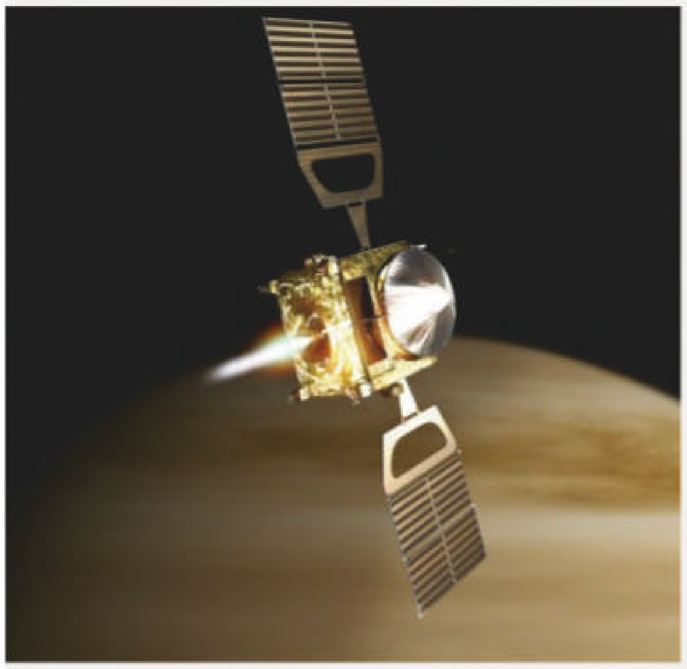
The main aspect of the book talks about the evolution of Earth as much as the evolution of humans, but is there a way we can learn about the evolution of the Solar System from all this as well?
Clearly there are a lot of links from Earth sciences to planetary sciences. I'm a planetary scientist myself; I focus on our next-door neighbour planet, Mars, and a lot of my colleagues who I work with have come from a geology or Earth science background. The knowledge of the processes on Earth - such as volcanism, glaciology or plate tectonics - can be applied to other planets also, whether that is Venus, Mars or the icy moons of Jupiter.

What quite often happens is we find something out about those other planets or moons and apply that knowledge back to Earth, so it completes a full cycle of understanding each other. For example, a lot of research on Venus and the runaway greenhouse effect that it has suffered has been helping us inform scientists on Earth about our own global warming from the carbon dioxide we're releasing as a species.



Above: The cover of Darnell's new book, *Origins: How the Earth Made Us*

Far left: The Milankovitch cycle brought Earth into the Ice Age that allowed our species to roam



Above: Portuguese explorers found the way to India using the night sky

Below: Venus has helped us understand how carbon dioxide affects climate change

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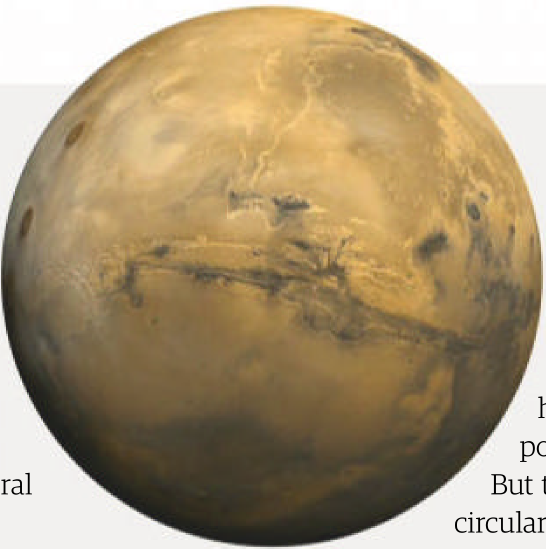


I talk about that in *Origins* - the problems that have been brought on by global warming currently driven by humans, and how that compares to natural periods of climate change.

Is there a way that humans could have an effect on other planets' climates, for example if humans went to Mars?

Humanity at the moment as a species - an industrial civilisation - is inadvertently driving climate change on Earth. There are activities that are changing our very environment. People are now talking about doing that deliberately [to other planets] only if we can work out how to do those processes in a controlled way.

There has been talk of doing it to other planets, such as Mars, and this is called 'terraforming'. How can you change the environment of Mars to make it more habitable and more hospitable for people to live in? How can you start pumping up its atmosphere? How can you start getting a stronger greenhouse effect on Mars to warm its surface, so that water can flow again? How can you start introducing and producing oxygen on Mars?

People talk about that sort of process being applied deliberately to Mars, so humans - in the far future - can live there.

The beginning of your book talks heavily about plate tectonics. How important are these to life on Earth?

Plate tectonics are one of those fundamental features of Earth as a planetary body. They have been running for billions of years and have had a profound influence on not just the history of human civilisations, but our origin in the first place.

We owe our very existence as an intelligent species to plate tectonics, and a lot of life on Earth owes its existence to plate tectonics and how they help regulate the climate of the entire planet. So one of the big questions for space is which other planets and moons have got plate tectonics on them?

So plate tectonics would be one of the biggest indications for life being able to evolve?

There are other signs of life that you look for, for example bacteria on Mars or bacterium in the oceans of Europa. But in terms of understanding how planets form and change over their lifetimes over billions of years of a planet's existence, plate tectonics is one of those key fundamental features.

If we're looking beyond our Solar System at the extrasolar planets [exoplanets], the process of plate tectonics is a key feature to be looking for in a planet to be habitable and host life. People also look for planets orbiting within the habitable zone of their star - the area where the temperature is not too hot and not too cold for liquid water. We would be looking for planets with an appropriate atmosphere; ideally it has a magnetic field to protect the atmosphere and any life from stellar winds and radiation and ideally things like plate tectonics.

How has the orbit of the Earth changed over its lifetime and what effect has that had on Earth?

The Earth orbits within the Sun's habitable zone. Earth has oceans and had the best possibility for life emerging here. But the Earth's orbit is not perfectly circular and it's not static. The Earth's orbit is constantly shifting, and so is the tilt of Earth's axis - it gently rocks backwards and forwards ever so slightly. These changes are known as the Milankovitch cycles and they deal with how much the Earth is tilting as well as how egg-shaped or circular Earth's orbit is. During this time they [Earth's tilt and orbit] start to fall into step with one another in a particular way that makes parts of the Earth colder, and every now and then they fall out of sync again and the Earth warms back up.

Those Milankovitch cycles have been extremely important for the last two to two-and-a-half million years of Earth's history because the planet of that period has been on the brink of glaciation; every time those cycles fall into sync with each other the Earth gets tipped into an ice age.

You might expect that in the Ice Age there were these four-kilometre- (2.5-mile) thick sheets of ice grinding their way down from the North Pole. You'd expect that it would create a very harsh environment for humanity. Indeed it does, but it also gave us, as a species, an incredible opportunity that was very influential in our story.

The Ice Age enabled us to migrate around the entire world. So we evolved in east Africa, as we talked about earlier with plate tectonics, and it was the Ice Age, climate fluctuations and ultimately this cosmic influence - from the Solar System, its planets and Earth's orbit shift - that lowered the sea levels and enabled humanity to literally walk around the world colonising Asia, down to Australia and more importantly across the Bering land bridge to North America.

How did the night sky, stars and astronomy in general mould civilisations?

Astronomy is one of the oldest sciences. You don't need any particular equipment to just look up at the sky on a nice, clear, dark night and spot these patterns. We've constructed constellations out of these combinations of stars and told stories and legends about them. But ultimately what people were doing was spotting stars that don't move - the sitting stars that make up the constellations - and then curiously spotting what appeared to be stars that wandered. They moved through the heavens and they weren't in the same place night on night or month on month. We now know those to be planets, rocky or gaseous bodies, a bit like the Earth but orbiting the same star as us. Over time we have come to understand what the stars are and how the Sun is also just another star but much closer.

But one of the key functions that stargazing and astronomy have played in our story was in navigation. You can measure the stars and measure the angles between a particular star such as Polaris - the North Pole star - and the horizon, and that will tell you the latitude on the Earth.

As Portuguese sailors were sailing around the west African coast, trying to find a sea route to India for the spice trade, sometime in the mid-1400s they passed the equator. This wasn't important just because they were exploring new land, but their system of navigation just broke down. They could no longer see Polaris because they had crossed the equator. Soon after they discovered another constellation in the southern hemisphere - the Southern Cross - that performs a similar function.

I love this story of using the stars to navigate your way across the oceans, to make sure you don't get lost in this vast expanse and get to where you need to be, but then also working out how to adapt that system when you start going to different parts of the world, like in the Southern Hemisphere, which Europeans hadn't explored before.

That sort of navigation is a forgotten art now, isn't it?

We kind of take it for granted now, yes. I'm always getting lost and the first thing I do when I can't quite work out where I am is reach into my pocket and get out Google Maps on my smartphone. You don't have to think about navigating anymore, and that's just over a quarter of a mile!

When you try and imagine what these early navigators were doing, like crossing the entire expanse of the Atlantic or Pacific Ocean, where they had not seen land for weeks upon weeks. Yet they had that confidence that they knew roughly where they were and where they were trying to get to in order to survive the voyage. It boggles my mind just how incredible it is when you think about it.

Now you have looked intensely into the deep history of the Earth, how do you see its future unfolding?

The whole of the book, *Origins*, is this fusion between history and science. It shows how the human story and the origins of our civilisations have been crafted and influenced by fundamental features of our planet. But then you can use this understanding and knowledge to look into the future, such as how the world is likely to change and how that will affect you and I and our everyday world.

We touched on a similar kind of topic already to do with climate change and how coal and oil was this wonderful resource to get us through the industrial revolution. This has led to the privileged, relaxed and comfortable lifestyle we have today. But it has unleashed this genie in a bottle. It has had these unintended consequences of putting too much carbon dioxide into the atmosphere and changing our climate. These are the problems we have to solve in the near future.

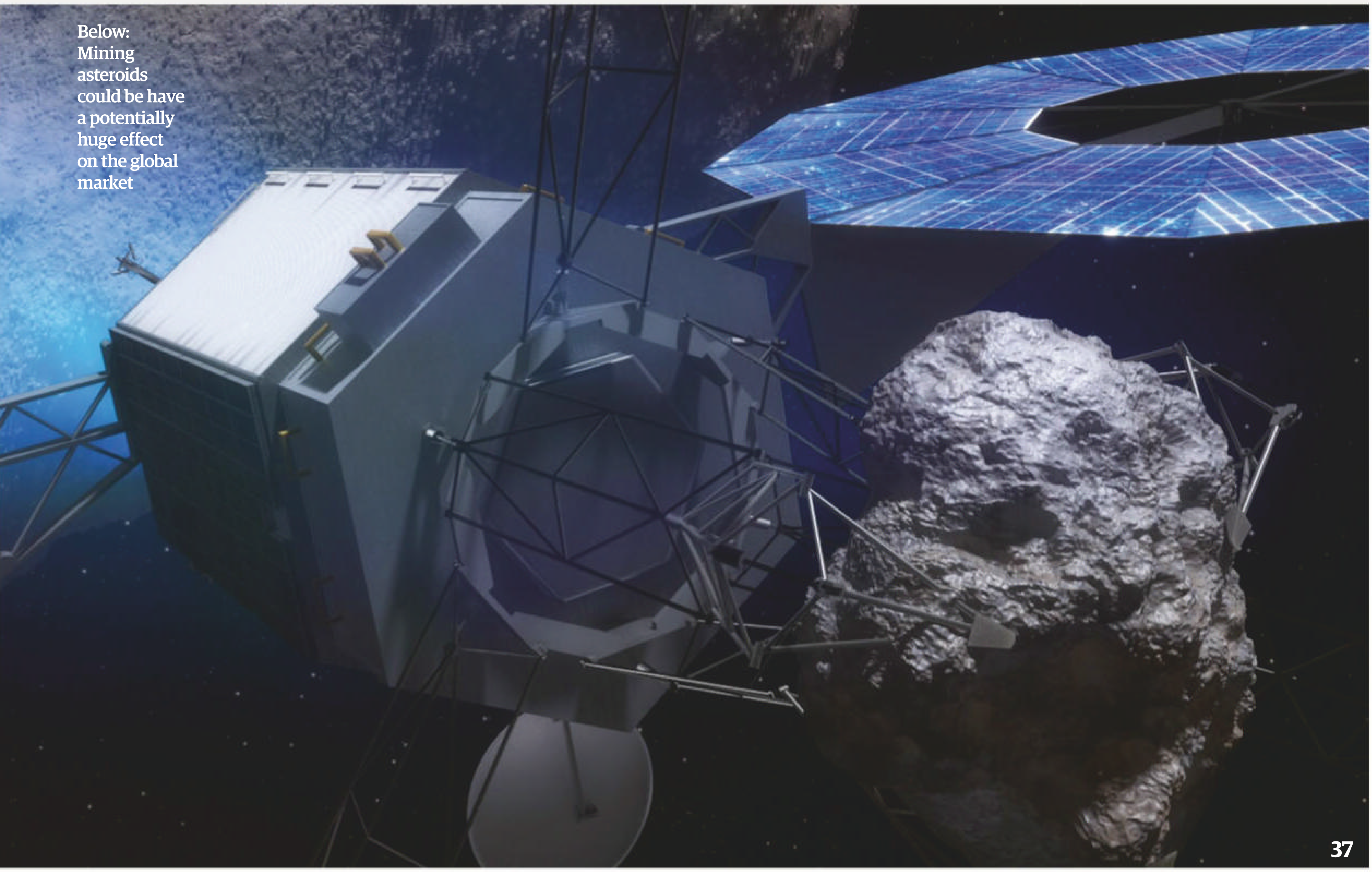
So by understanding the processes that I talk about in *Origins*, and how they affect human history, it will also tell us about our own future as a species and what we'll have to do for ourselves if we were to live on Mars or elsewhere.

What are your thoughts on the mining of asteroids?

So there's a whole chapter in *Origins* about the importance of metals in human history. Clearly we've gone through the Bronze Age, the Iron Age and today we're very much in the Steel Age, the Aluminium Age, if not even the Silicon Age - where we use these non-metals for computers, solar panels and so on. The problem with all those exotic metals is they are quite rare and hard to get at on Earth. There's a limited supply and they're hard to recycle from the electronics we use.

Therefore there is a huge demand and potentially a lot of money to be made by going to the asteroids and mining those as well as mining these resources on Earth. If you pick the right asteroid, this one lump of rock just a couple of kilometres across could be worth trillions upon trillion of pounds on the global market for different metal.

> "We've constructed constellations out of these combinations of stars and told stories and legends about them"



Below: Mining asteroids could be have a potentially huge effect on the global market

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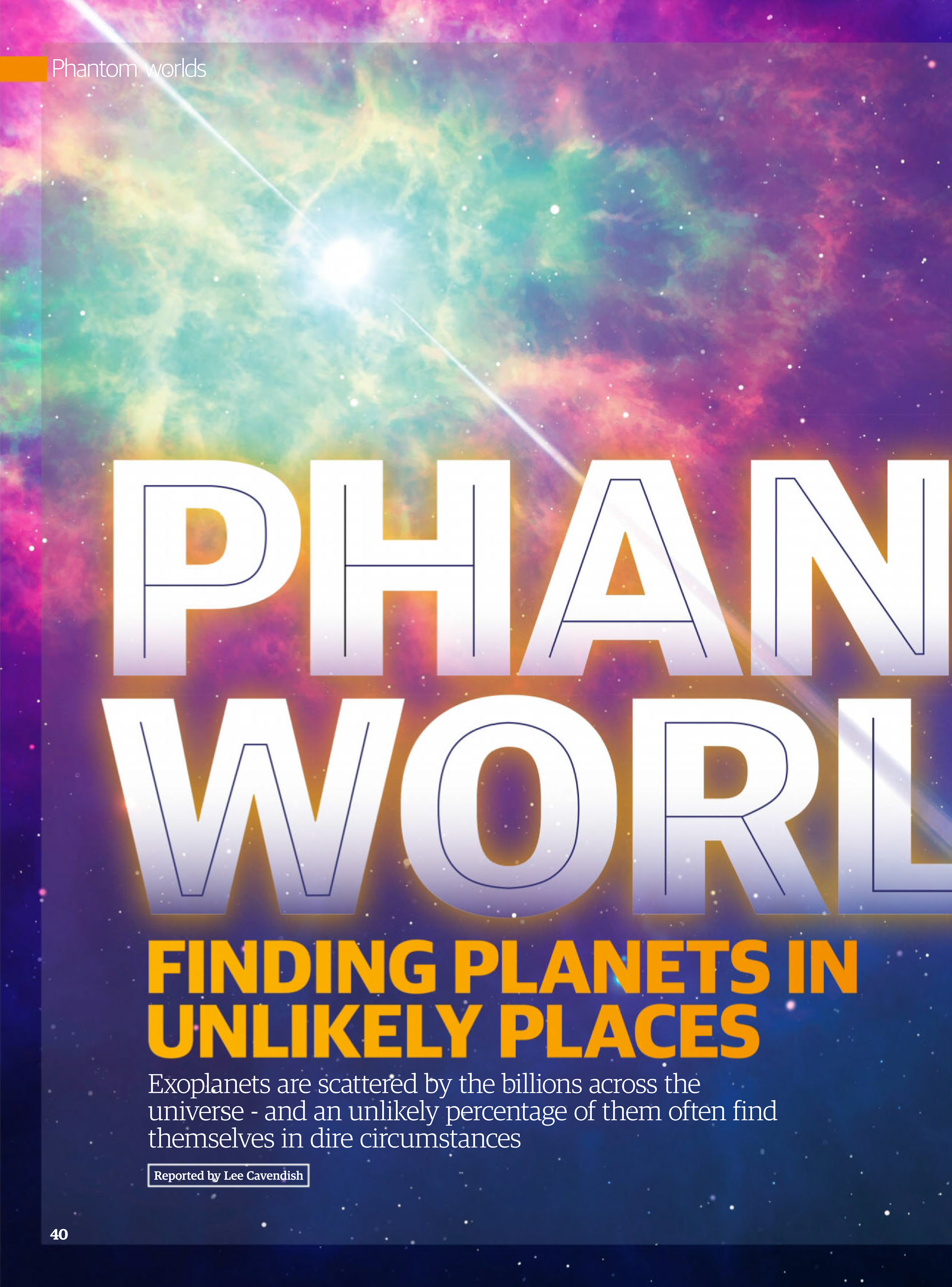


PHAN WORL

FINDING PLANETS IN UNLIKELY PLACES

Exoplanets are scattered by the billions across the universe - and an unlikely percentage of them often find themselves in dire circumstances

Reported by Lee Cavendish

TOM DS

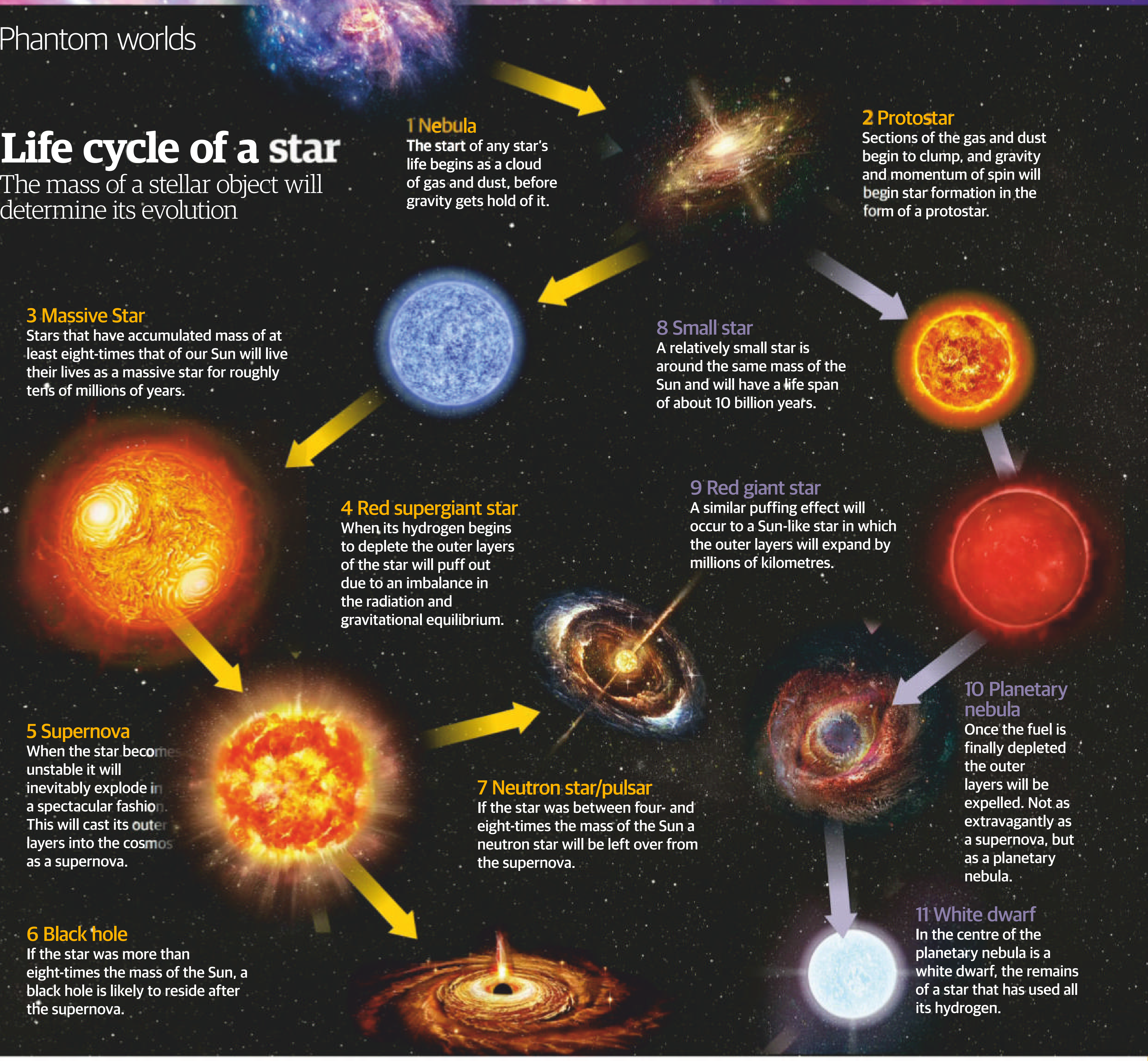
© Mark Garlick / Science Photo Library

Roughly 4.6 billion years ago the Sun was born from the collapse of a nebula – a giant cloud of gas and dust. Since then planets, moons, asteroids, comets and other debris have formed to give rise to the Solar System. In another 5 billion years the Sun will begin its transition into a red giant star, swelling up due to the lack of internal fuel to power nuclear fusion.

Just by looking at the sky you can see that our Solar System has the ideal conditions for planet formation, but what about more extreme conditions? What about the stars that aren't a G2V-type, Sun-like star? What about the stars that haven't been able to make it, or have evolved to the concluding phases of their lives? These questions are a hotly studied

Life cycle of a star

The mass of a stellar object will determine its evolution



1 Nebula
The start of any star's life begins as a cloud of gas and dust, before gravity gets hold of it.

2 Protostar
Sections of the gas and dust begin to clump, and gravity and momentum of spin will begin star formation in the form of a protostar.

3 Massive Star
Stars that have accumulated mass of at least eight-times that of our Sun will live their lives as a massive star for roughly tens of millions of years.

4 Red supergiant star
When its hydrogen begins to deplete the outer layers of the star will puff out due to an imbalance in the radiation and gravitational equilibrium.

5 Supernova
When the star becomes unstable it will inevitably explode in a spectacular fashion. This will cast its outer layers into the cosmos as a supernova.

6 Black hole
If the star was more than eight-times the mass of the Sun, a black hole is likely to reside after the supernova.

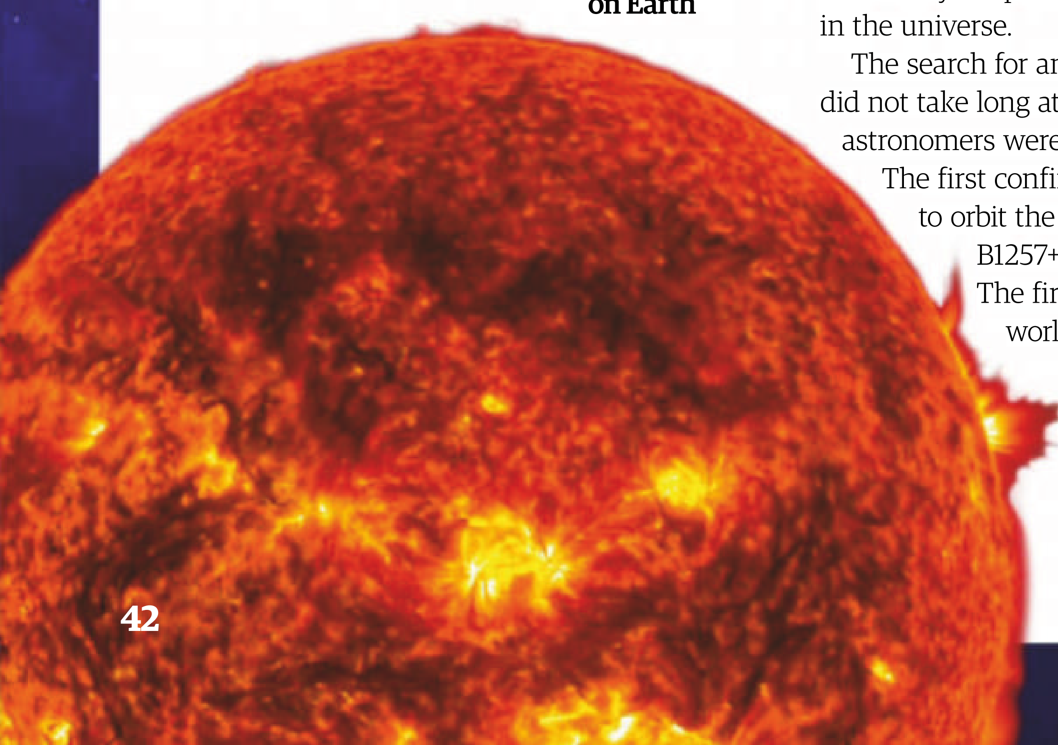
7 Neutron star/pulsar
If the star was between four- and eight-times the mass of the Sun a neutron star will be left over from the supernova.

8 Small star
A relatively small star is around the same mass of the Sun and will have a life span of about 10 billion years.

9 Red giant star
A similar puffing effect will occur to a Sun-like star in which the outer layers will expand by millions of kilometres.

10 Planetary nebula
Once the fuel is finally depleted the outer layers will be expelled. Not as extravagantly as a supernova, but as a planetary nebula.

11 White dwarf
In the centre of the planetary nebula is a white dwarf, the remains of a star that has used all its hydrogen.



Below: The Sun has provided the kindest conditions for life to thrive on Earth

topic as astronomers around the world lock in on extrasolar planet - or exoplanet - research. These astronomers are not only looking for a 'new Earth', they are trying to figure out what kind of environments can accommodate planets and how many exoplanets are hidden away from us in the universe.

The search for an unusual planetary system did not take long at all - for many years before astronomers were convinced they were out there. The first confirmed exoplanets were found to orbit the millisecond pulsar named PSR B1257+12 some 2,300 light years away. The first-ever 'pulsar planets', doomed worlds that orbit a dead star, were Poltergeist (PSR B1257+12 c) and Phobetor (PSR B1257+12 d), announced by astronomers Aleksander Wolszczan and Dale Frail on 9 January 1992. These two planets orbit the pulsar at roughly the same distance that Mercury orbits the Sun.

However, there are not many other known pulsar planets, as Dr Dimitri Veras, an assistant professor at the University of Warwick, UK, tells **All About Space**: "A type of dead star which did experience a supernova is called a pulsar, and a total of four planets are known to orbit pulsars." It is not much of a surprise that such a small number of these planets exist due to the incredibly hostile nature of their environment. A pulsar is the last stage of a massive star's life, as long as the star originally had four- to eight-times the mass of the Sun. After billions of years, but a shorter time period than our Sun, the star will explode as a supernova and leave behind its dense, powerful core, known as a neutron star. A neutron star can rotate rapidly, sending out jets of material and radiation from its poles. If Earth is in their line of sight astronomers pick up these rapid flashes of light, known as pulsars.

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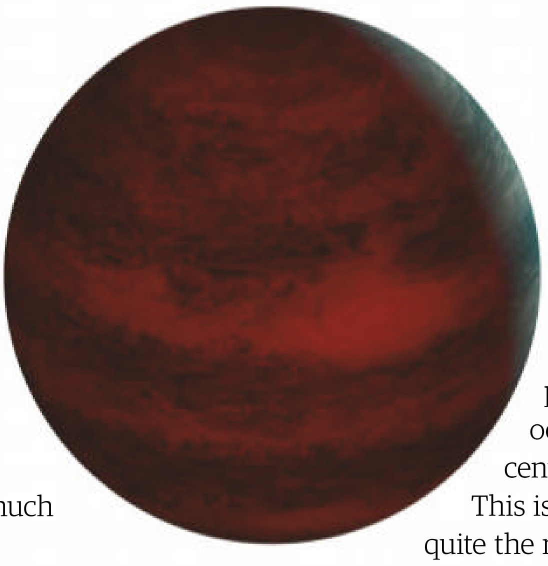


These stars are tremendously dense; if you were to somehow get a teaspoon of the stuff it would weigh a billion tons. Because these stars are so dense they are very hot and release a lot of radiation in gamma rays, X-rays, ultraviolet rays and so on. This is not healthy for a planet. If the Earth was constantly bombarded by these levels of radiation there is no way life would survive in any form.

A study released by Dr Alessandro Patruno from Leiden University, The Netherlands, and Dr Mihkel Kama of the University of Cambridge, UK, stated that planets could be habitable around pulsars. In order to make this claim these astronomers deduced the theoretical 'habitable zone' around a pulsar – the distance a planet would have to be from the pulsar in order for water to exist as a liquid. These results highlighted the specific criteria a planet must meet in order to survive here: a maximum distance from the pulsar than the Earth is to the Sun, the planet must be a super-Earth – a mass between one- and ten-times our Earth – and the atmosphere must be as thick as the conditions on the deepest ocean floors. If the atmosphere was relatively thin then the pulsar winds would strip it away within a thousand years – which is no time for life to evolve.

The origins of these planets are unknown, but there are two likely options. The first is that the planet was formed before the supernova from primordial debris around the same time as the birth of the star, and was far away enough to survive the supernova. The other side of the coin suggests that these planets formed from debris surrounding the pulsar, much like a second-generation planet.

In 2006 a team of researchers used NASA's Spitzer Space Telescope to uncover new evidence that suggests second-generation planets were formed around a pulsar called 4U 0142+61, 13,000 light years away. "We're amazed that the planet-formation process seems to be so universal," says Deepto Chakrabarty of the Massachusetts Institute of Technology, principal investigator of the research. "Pulsars emit a tremendous amount of high-energy radiation, yet within this harsh environment we have a disc that looks a lot like those around young stars where planets are [being born]."

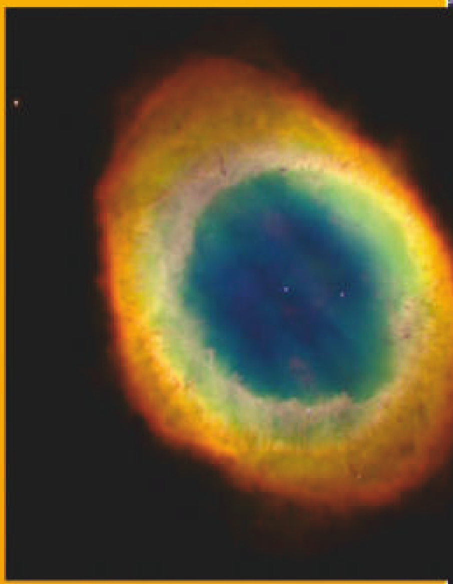
Now what if a planet was to escape before a pulsar could pepper it with harmful radiation? This is hypothetically possible, as a planet around a red supergiant could be expelled in the following supernova and cast away as a 'rogue planet'. In fact, Veras even claims that "there could be up to one giant rogue planet for every star".

"This possibility has not been considered in depth in the astronomical literature, probably because supernovae occur rarely – about once per century in our galaxy," says Veras. This is unfortunate as this would be quite the revelation in terms of planets existing in unlikely situations. To think that there could potentially be thousands or even millions and billions of planets hidden in the cold, dark emptiness of space that are undetectable without a star's light is a intriguing thought.

Once ejected these rogue planets don't have many options except to wonder through space alone. They bring a whole different meaning to the term 'phantom' as they ghost through the universe until they find a new home. "Simulations have shown that planetary systems can capture rogue planets, although the process is rare and depends on several factors," says Veras. This could mean that planets around dead stars could be imposters sent from another system, but then again there are so many unknown factors to take into account in this scenario, with such little data it would be outlandish to make any definitive claims.

When looking at dead stars the mind can't help but relate back home, bringing thoughts of what will happen to our own Sun at the end of its life. When the Sun runs low on hydrogen to burn its outer layers will swell. "The Sun will engulf Mercury and Venus. Mars, Jupiter, Saturn, Uranus and Neptune will all survive, and the fate of the

> "Pulsars emit a tremendous amount of high-energy radiation, yet within this environment we have a disc" **Deepto Chakrabarty**



From above, clockwise: 'Rejuvenated planets' would theoretically emit a youthful glow of infrared light

Eventually the Sun will form a planetary nebula – hopefully this will look beautiful

Veras states that rogue planets could be captured by other planetary systems

NASA's Spitzer Space Telescope has played an important role in analysing exoplanets over the years

Timeline

The hunt for potentially habitable planets

PSR B1257+12 c and d (Poltergeist and Phobetor)

Discovered
January 1992
Type of host star
Pulsar
Distance from Earth
2,300 light years
These were the first two exoplanets ever discovered.

Gliese 876 b

Discovered
June 1998
Type of host star
M-type red dwarf
Distance from Earth
15 light years
This was the first exoplanet discovered around a red dwarf star.

Iota Draconis b

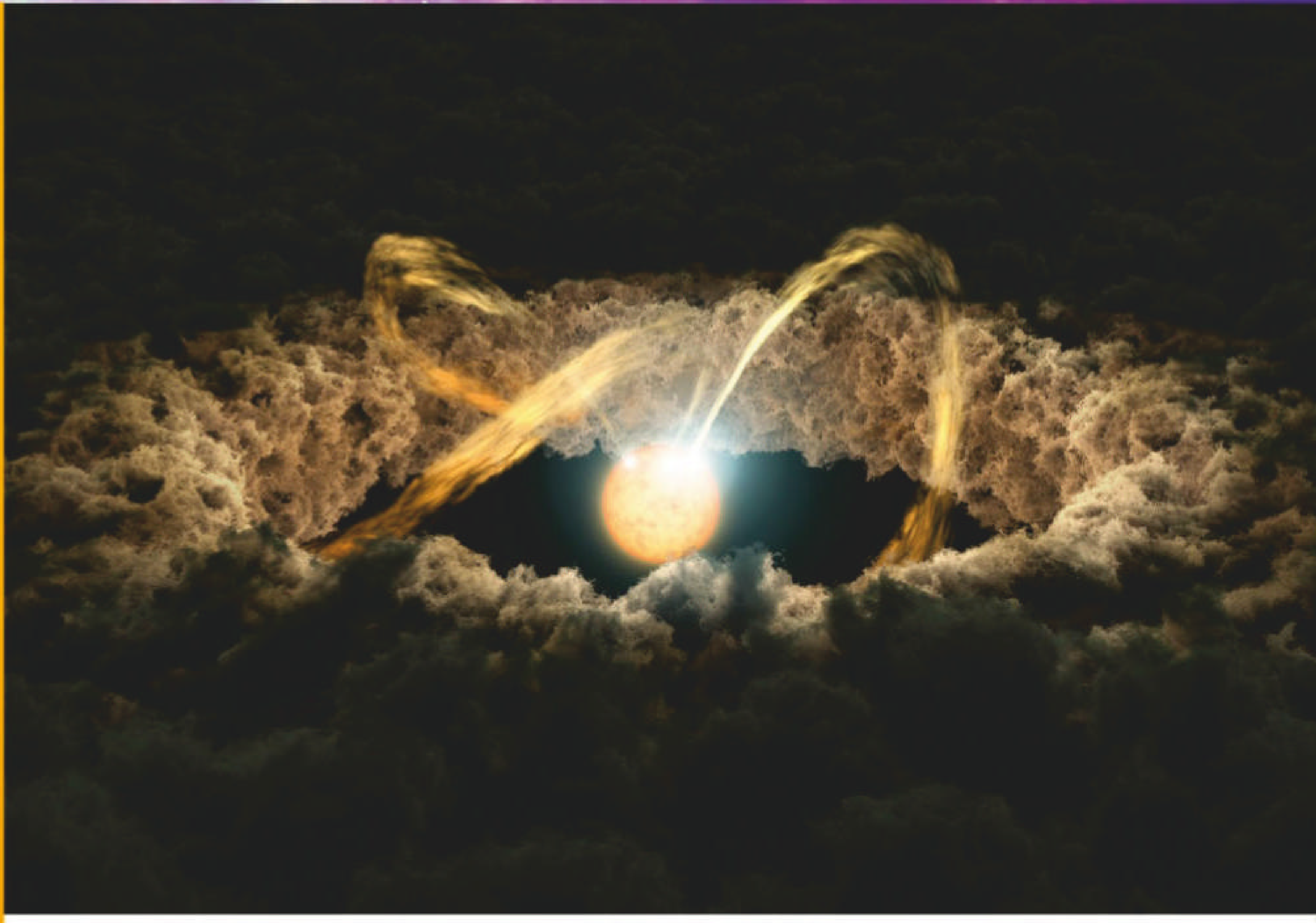
Discovered
January 2002
Type of host star
K-type giant star
Distance from Earth
Iota Draconis b was the first planet discovered around a giant star, providing evidence for how planets survive extreme conditions.

Proxima Centauri b

Discovered
August 2016
Type of host star
M-type red dwarf
Distance from Earth
This is the closest exoplanet to our Solar System ever discovered.

TRAPPIST-1b, c, d, e, f, g and h

Discovered
February 2017
Type of host star
M-type red dwarf
Distance from Earth
Astronomers announced they had found seven potentially habitable exoplanets orbiting a red dwarf star.



> "A type of dead star which did experience a supernova is called a pulsar, and a total of four planets are known to orbit pulsars" **Dr Dimitri Veras**

Above: The evolution of a star depends upon the amount of mass accreted during its formation

Below: Xu states that there is a chance a habitable planet could exist around a white dwarf

Earth is unclear," explains Veras. "The asteroid belt will likely be destroyed by rotational spin-up due to the Sun's increased luminosity on its giant branch stellar evolutionary phase."

Afterwards the outer layer will be expelled as a beautiful planetary nebula. What's left is a white dwarf star that is 54 per cent of its original mass. This dense leftover core could also become the host star of a planetary system. Unfortunately there has been no definitive system confirmed yet, but there has been extremely compelling evidence found in attempting to form one.

For instance, in June 2015 a group of astronomers used Spitzer to observe a white dwarf system and found there to be excessive infrared radiation. It is known that white dwarfs have a circumstellar disc - which can also be referred to as 'polluted' white dwarfs - that could well be scattering the stars' light and providing this infrared boost. However, in the case of white dwarf PG 0010+280, there is the strong possibility that a planet formed from the pollution and gives out the fresh infrared glow that new planets emit. "So far we have detected about 40 white dwarfs with infrared excesses, and the consensus is that the infrared excess comes from dust discs surrounding the white dwarfs. In all those cases the white dwarf would show signatures in its spectra from accreting material from the circumstellar disc," Dr Siyi Xu, an assistant astronomer at the Gemini Observatory, Hawaii, and a member of this research team, tells **All About Space**. "PG 0010+280 is the only outlier with a strong infrared excess but no pollution. That is why we speculated in our 2015 paper that another possibility is that the infrared excess comes from a rejuvenated planet - a planet that accreted a lot of material during the red giant stage of the star and it is hot and young again.

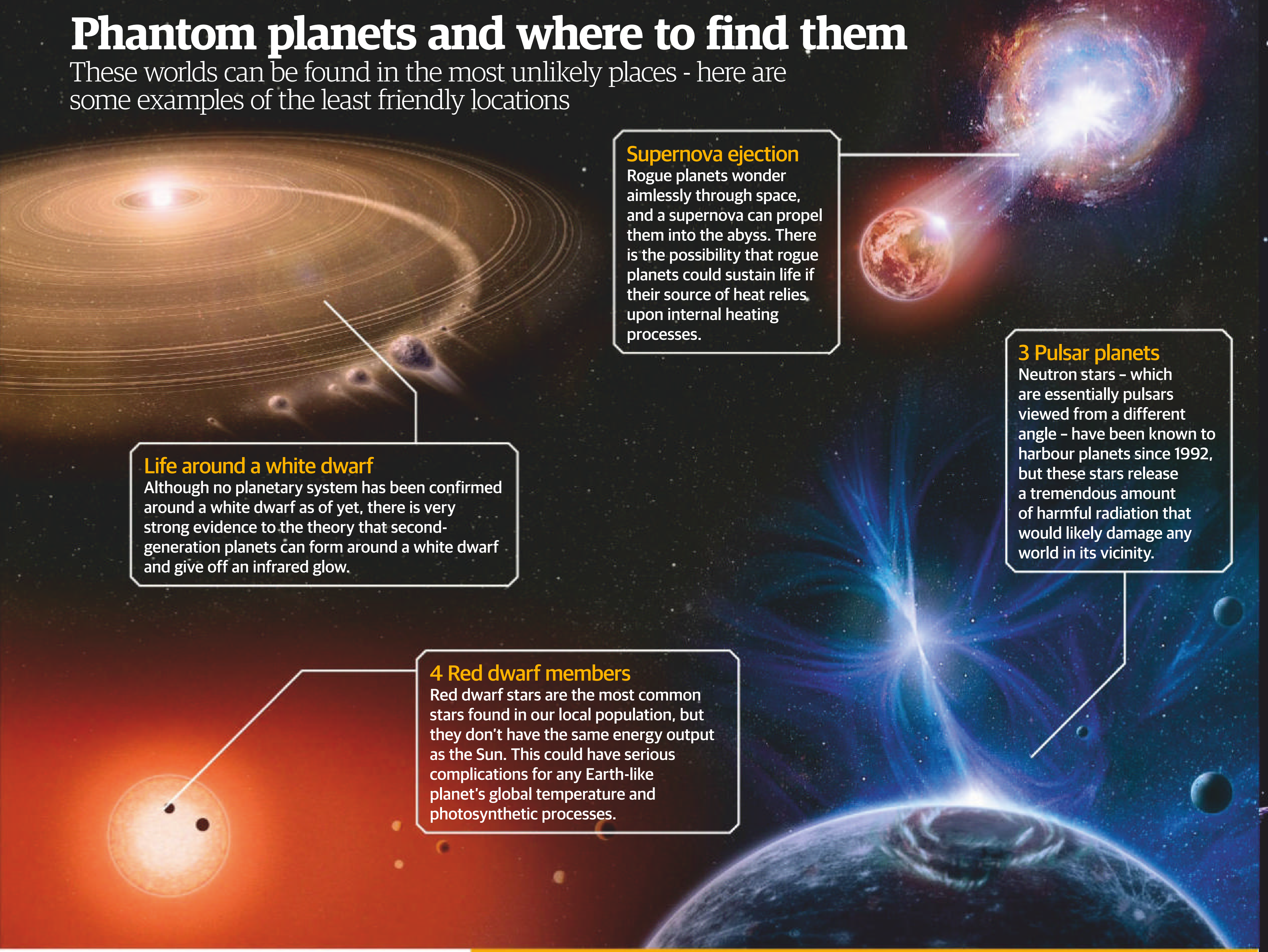
"Since 2015 there have been a few more discoveries of white dwarfs with infrared excesses, but they are mostly polluted. There have not been new discoveries of PG 0010+280-like objects." Similar to pulsar planets, there is the possibility that a second generation of phantom worlds could form from the death of their host star.

There are also the stars that don't quite make it. There are stars that don't envelop enough material during formation to reach the heights of the Sun, and these are called red dwarf stars. These stars are roughly between 7.5 and 50 per cent the mass of our Sun and only burn to temperatures of around 3,500 degrees Celsius (6,380 degrees Fahrenheit), which is only roughly 60 per cent of the Sun's effective temperature.

These cooler stars are much more abundant in Earth's vicinity, with scientists predicting 20 out of 30 stars nearest to Earth are red dwarfs. As it happens, the nearest star to Earth, Proxima Centauri, located just four light years away, is a M-type red dwarf star with its own Earth-like planet

Phantom planets and where to find them

These worlds can be found in the most unlikely places - here are some examples of the least friendly locations



Supernova ejection
Rogue planets wonder aimlessly through space, and a supernova can propel them into the abyss. There is the possibility that rogue planets could sustain life if their source of heat relies upon internal heating processes.

Life around a white dwarf
Although no planetary system has been confirmed around a white dwarf as of yet, there is very strong evidence to the theory that second-generation planets can form around a white dwarf and give off an infrared glow.

3 Pulsar planets
Neutron stars – which are essentially pulsars viewed from a different angle – have been known to harbour planets since 1992, but these stars release a tremendous amount of harmful radiation that would likely damage any world in its vicinity.

4 Red dwarf members
Red dwarf stars are the most common stars found in our local population, but they don't have the same energy output as the Sun. This could have serious complications for any Earth-like planet's global temperature and photosynthetic processes.

held within its habitable zone. As tantalising as it seems to have an Earth-like planet so close to Earth itself, however, Proxima b's habitability is sadly deemed 'unlikely', as astronomers witnessed a super flare erupt from Proxima that would have doused the planet in huge amounts of ultraviolet radiation.

Red dwarf targets are not as doomed as the pulsars, white dwarfs or even Proxima b, however, as these stars could hold some of the most exciting prospects for life beyond our Solar System. A popular example is TRAPPIST-1, the ultra-cool red dwarf star, and its seven planets. This star is about 12 per cent the size of our Sun and burns at a measly 2,220 degrees Celsius (4,000 degrees Fahrenheit), yet it holds planets that astronomers believe could hold something special.

Possibilities are endless when it comes to the universe, and no one can deny that one of these phantom wolds around seemingly dead, insignificant stars could prove to be some of the most stimulating prospects around. These systems could even hold clues as to the fate of the Solar System and what is to happen to Earth.

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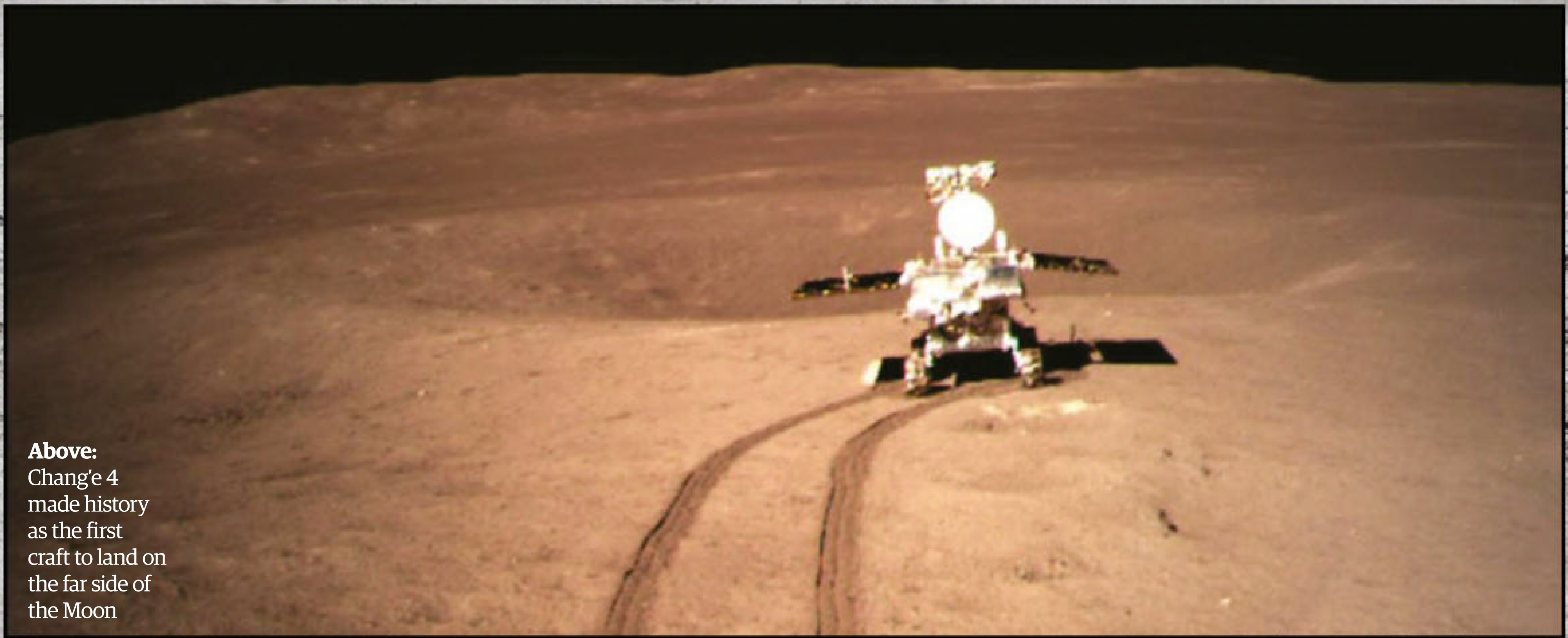
Right: The TRAPPIST-1 planetary system is arguably the most exciting prospect within exoplanet research

CHINA LANDS ON THE FAR SIDE OF THE MOON

Chang'e 4 probe brings joy in the New Year as it becomes the first rover to touch down on uncharted territory

Reported by Lee Cavendish



Above: Chang'e 4 made history as the first craft to land on the far side of the Moon

© NASA; CNSA

What do the China National Space Administration (CNSA) and Pink Floyd have in common? They both have hits with the dark side of the Moon. Although NASA's New Horizons made headlines entering the New Year with exciting new images of an extremely distant Kuiper Belt Object, CNSA's Chang'e 4 probe also made history by becoming the first object to land on the dark, unexplored side of the Moon.

The unmanned space probe touched down in the South Pole-Aitken Basin at 10:26am Beijing Time (2:26am GMT) on 3 January 2019. After its soft landing the spacecraft, with a rover residing inside ready for later deployment, sent back its first images of the far side of the Moon. These images have increased excitement around the mission as it looks to examine the dark side up close. After having made a successful descent from a 15-kilometre (nine-mile) altitude the probe landed in the Von Kármán Crater and unfolded its antennae and solar panels under the control of space engineers in Beijing.

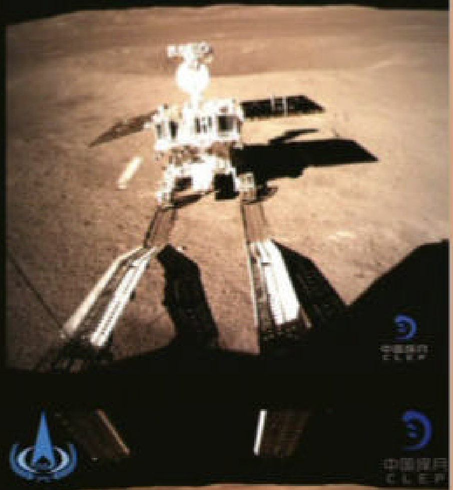
The far side of the Moon is very different to the familiar face that is tidally locked in Earth's direction. It has been seen by many orbiters over the years, but it has never had a man-made rover to keep it company due to the difficulty in communication. With it being on the far side the Moon blocks direct communication, which is why Chang'e 4 has the Queqiao, meaning Magpie Bridge in Chinese, relay satellite.

This spacecraft is placed at a gravitational parking spot between the Earth and Moon 65,000 kilometres (40,000 miles) from the Moon' surface. This parking spot, also referred to as the second Lagrangian point (L2), can see both the far side of the Moon and Earth and can therefore provide constant communication.

> "The far side of the Moon is very different to the familiar face that is tidally locked in Earth's direction"

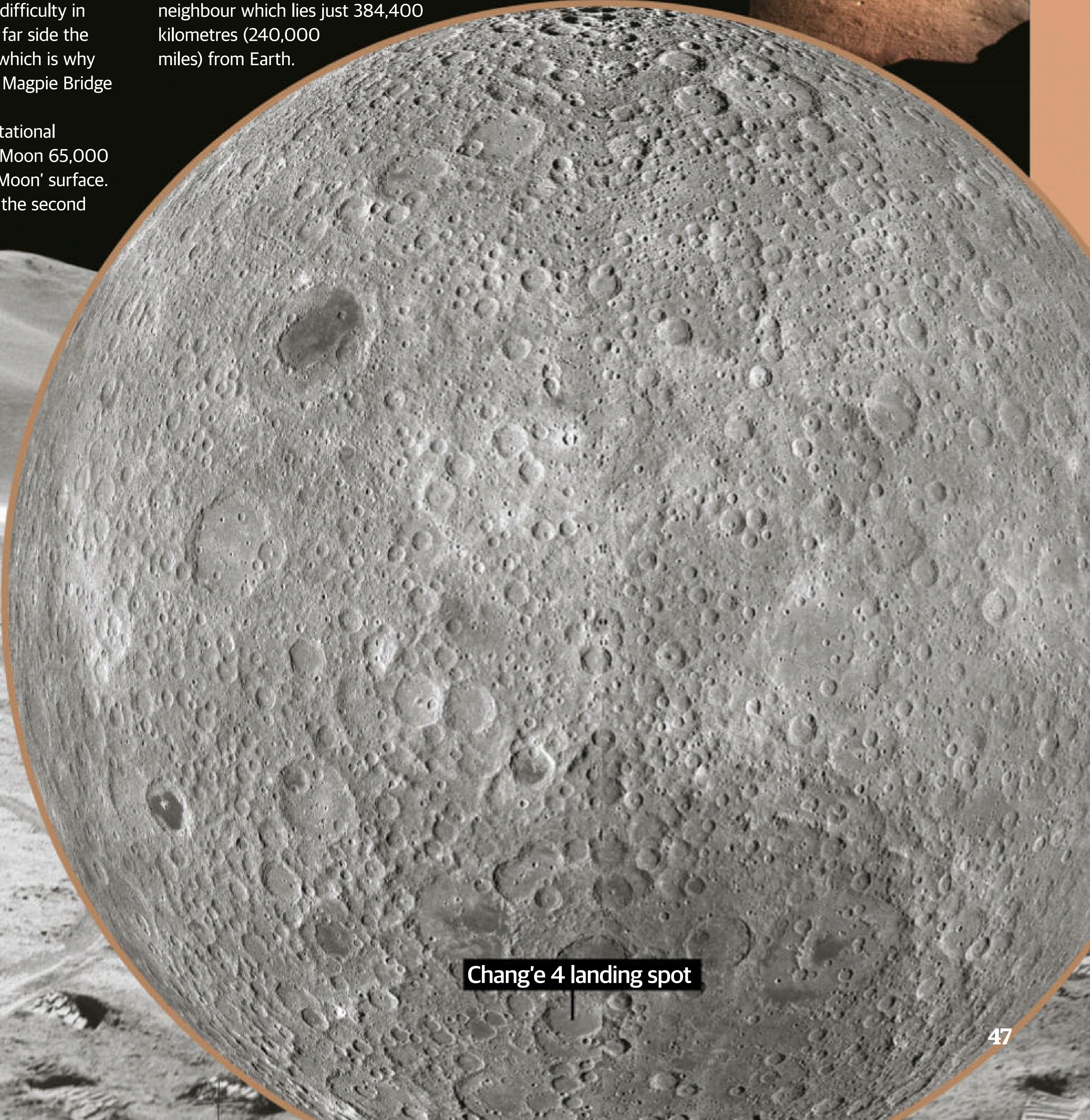
The Chang'e 4 probe includes a total of eight payloads – two of which were developed by the Swedish Institute of Space Physics and Kiel University in Germany – which will provide a deep examination of the Moon. The aim of this mission is to conduct low-frequency radio astronomical observations that will survey the surrounding terrain and landscape, detecting mineral composition to deduce if it's any different from the near-facing side and measure the neutron radiation and neutral atoms.

Due to little exploration of the far side in the past scientists can only infer that the lunar crust is much thicker compared to the near side. The reality of the situation is that no one knows for sure, however, and only by conducting these sorts of exploration missions and further thorough analysis of the data can humans finally paint a full picture of our celestial neighbour which lies just 384,400 kilometres (240,000 miles) from Earth.



Right: The lander sent back its first images of the Moon's uncharted far side soon after its soft landing

Below: Chang'e 4 touched down on the landing site within a crater called Von Kármán in the South Pole-Aitken Basin



THE NEED TO REDESIGN THE SPACESUIT

If astronauts are to set foot on a planetary surface they'll need to be suited and booted with some new wear

Reported by David Crookes

© NASA

Left: Spacesuits are imperative in performing extravehicular activity

Bottom left: The current spacesuits are different to the ones used back in 1961, but they are still in need of an update

Name an iconic item of clothing worn during the 1960s and chances are you'll cycle through the usual suspects, from miniskirts through to the PVC dress. Some will have graced the western world's catwalks during this most fashionable of decades, but one revolutionary garment never quite made it to Paris or Milan yet has proved truly out of this world.

We're talking, of course, about the spacesuit - the garment which has proven essential in allowing astronauts to survive in the harsh environment of outer space and made travel there and back much safer. Suits have been part and parcel of space travel from the earliest days - cosmonaut Yuri Gagarin wore the first spacesuit, the SK-1, in space on the iconic flight on 12 April 1961. As such, they have allowed humans to fly into low Earth orbit, set foot on the Moon and perform vital duties outside of the International Space Station (ISS) - yet they are far from perfect.

"Spacesuits are notoriously bulky, heavy, immobile and risky," says Ted Southern, president of Final Frontier Design, a company which develops safety garments to enable future human space travel. To that end, Southern knows exactly where and why improvements are necessary. For while past and current spacesuits have been more than adequate for fleeting visits to the lunar surface and working on the ISS, future plans and ambitions are ensuring the race to redesign them is very much on.

Spacesuits are not merely an item of protective clothing. They are anthropomorphic, miniature machines with the complexity of a larger space vehicle. Each contains about 2,000 parts, every one critical for safeguarding the life of the wearer and allowing them to perform tasks. Trouble is, the current crop are ageing, and they are essentially unchanged from those used throughout the Space Shuttle program. Indeed, the intravehicular activity (IVA) suits are pretty much the same as those worn in 1959 and, when you consider the need for lighter, more reliable suits, especially for the forthcoming space tourism market, it's clear new materials and designs are needed.

What we are seeing now are bold attempts to drag spacesuit design into the 21st century while smashing the manufacturing duopoly which has existed for decades. In doing so designers are tackling the orange 'pumpkin' Advanced Crew Escape Suit (ACES), IVA suits and the current Extravehicular Mobility Unit (EMU) - that is, the white outfits used by astronauts operating outside of a spacecraft in Earth's orbit. "The EMU was designed in the 1970s for the Space Shuttle," explains Southern. "But although it has been upgraded over the years to last for longer and longer missions, including the International Space Station, it cannot last much longer in terms of time."

There are clear reasons for this. The simplest is that current stock levels for extravehicular spacesuits is low, and they are expected to last for just five more years. "There are only 12 EMUs left, and some vendors don't even exist, so it's not as simple as ordering more," says Southern. Furthermore, EMUs - despite offering dexterity and flexibility, allowing astronauts to breathe, dealing with waste and regulating temperature, among many other features - will need to cope with extra demands placed upon them.

That's because NASA - pushed along by its former administrator Charles Bolden - is seeking a greater number of human-focused missions. The US agency proposes to put boots on the Moon once more, and there are plans for future human travel to Mars. And yet, as Southern states, "Current suit systems do not work well in dusty environments like the Moon or Mars. Next-generation missions will involve longer duration and longer distance from Earth, which will drive up requirements for reliability." It's abundantly clear that a whole new approach to spacesuit design is urgently required.

So what direction are they heading in? One of the top spacesuit designers is Amy Ross who works at NASA's Johnson Space Center. She helped pioneer a new glove design in the 1990s to replace the 4000 series EVA glove introduced in 1985, and she has also worked on new pressure garments and better surface EVA suits.

More recently, however - with the focus switching back towards manned exploration of other solar bodies - Ross has been instrumental in the creation of the Z-2 spacesuit designed for setting foot on the surface of the Moon or Mars. It's one of a number of designs under consideration and it more than surpasses the basic Apollo A7L spacesuits worn by Apollo 11 astronauts Neil Armstrong and Buzz Aldrin on the Moon in 1969.

"A spacesuit for the lunar surface hasn't been designed and tested since the Apollo program almost 50 years ago," says Vinita Marwaha Madill, space operations engineer at the European Space Agency (ESA) and founder of Rocket Women.

"The spacesuit technology developed during the mid-20th century was originally designed for short-duration missions to the Moon, with the longest stay being 75 hours during Apollo 17. The 1960s and 1970s were an incredible era for space exploration, however, we haven't actually stepped foot on the Moon for a long 45 years. So we will need to design a suit to allow human lunar exploration to proceed."

Certainly, the Z-2 spacesuit, designed for maximum astronaut productivity on a planetary surface, looks promising. Created to allow for easy exploration, sample collection and manoeuvring, its use of advanced composites makes it highly durable and lightweight. Adjustable across the waist and shoulder it can fit many sizes of crew member, and because it is entered by a rear port it can dock outside of a landing craft to make it easy to climb into - something astronauts using the EMU can only dream of.

> "Spacesuits are notoriously bulky, heavy, immobile and risky" **Ted Southern**

The Z-2 also considers the need for astronauts to walk, so special attention has been paid to the waist and hip joints, as well as a sturdy boot which, unlike an EMU, was not simply hard-soled. To figure out the best possible shoe the designers observed the way astronauts put pressure on their feet at different gravities. What's more there has been work on robotic assistance, using motors in the limbs of the suit to detect motion and push the suit in the desired direction.

Not that NASA is moving forward entirely by itself. Other space agencies around the world are also involved in the pursuit of the new. The European Space Agency (ESA), for example, is working alongside its counterparts in the US, Japan, Canada and Russia, and everything is on the table. The hope is that suits can be much more simplistic than today yet prove far more effective. In that sense they'd be maintainable far from Earth, which will be crucial for long-haul human missions.

One of the missions under consideration is the joint-venture Lunar Orbital Platform-Gateway which will eventually take humankind a thousand-times farther into the Solar System than the ISS. Madill

THE DIFFERENT KINDS OF SPACESUIT

NASA and the Russian Federal Space Agency (ROSCOSMOS) currently lead the way

Extravehicular Mobility Unit

Name of space agency/private company: NASA
Notable missions: Space Shuttle missions, International Space Station

Pros
+ Reusable
+ 14 layers of protection
+ Stood the test of time
+ Mobile life-support system

Cons
- Lacks manoeuvring capability
- Not many left
- Need for greater reliability
- Use ageing technology

Orlan MKS spacesuit

Name of space agency/private company: ROSCOSMOS
Notable missions: International Space Station

Pros
+ Enter via rear hatch
+ Automated environmental control
+ Lighter than EMU
+ Built-in computer

Cons
- Too bulky to return to ground
- Not modular so size restrictions for cosmonauts
- Tanks need to be replaced when empty

Sokol IVA suit

Name of space agency/private company: ROSCOSMOS
Notable missions: International Space Station

Pros
+ Rescue suit worn by astronauts on board the Soyuz spacecraft
+ Good field of view
+ Quick to put on thanks to zippers
+ Handy central placement of pressure-relief valve

Cons
- Intended purely for use on board a spacecraft
- Doesn't withstand thermal variations
- Not intended to be worn for long durations
- Introduced as far back as 1973

Advanced Crew Escape Suit

Name of space agency/private company: NASA
Notable missions: Space Shuttle missions

Pros
+ Integrated pressure bladders and ventilation system
+ Pressure helmet designed to reduce glare
+ Textured gloves for grip of controls
+ Black leather boots that reduce swelling

Cons
- Cannot be worn during spacewalks
- Intended purely for the launch and landing of a space shuttle
- Bright orange – not exactly fashionable
- Does not offer great mobility

© NASA; Nikitov; Vassili Petrovitch

SUGGESTED NEW DESIGNS

A look at the spacesuits which could end up replacing the current crop

Starliner spacesuit

Name of space agency/private company: Boeing

Key features

- ✓ **Lighter and more flexible**
- ✓ Soft helmet with zipper closure
- ✓ **Touchscreen-sensitive gloves**
- ✓ Mobility joints in shoulders and elbows
- ✓ **Dual-suit controller to maintain pressure**

Z-2 spacesuit

Name of space agency/private company: NASA

Key features

- ✓ **Hard upper torso**
- ✓ Made for wearing in space and on planetary surfaces
- ✓ **Rear-entry hatch**
- ✓ Bubble helmet for wide field of view
- ✓ **Carbon dioxide continuously removed**

Modified Advanced Crew Escape Suit

Name of space agency/private company: NASA

Key features

- ✓ **Based on Advanced Crew Escape Suit**
- ✓ Increased mobility in comparison and on planetary surfaces
- ✓ **Closed-loop system to preserve resources**
- ✓ Intended to support crews flying to the Moon or Mars
- ✓ **Full-pressure suit for ascent and entry during flight**

Prototype eXploration Suit (PXS)

Name of space agency/private company: NASA

Key features

- ✓ **Entered via the rear**
- ✓ Focused on improving suit fit
- ✓ **Seeking to minimise the amount of equipment needed**
- ✓ Can be customised with 3D-printed components
- ✓ **Compatible with suitports**

Final Frontier Design IVA space suit

Name of space agency/private company: Final Frontier Design

Key features

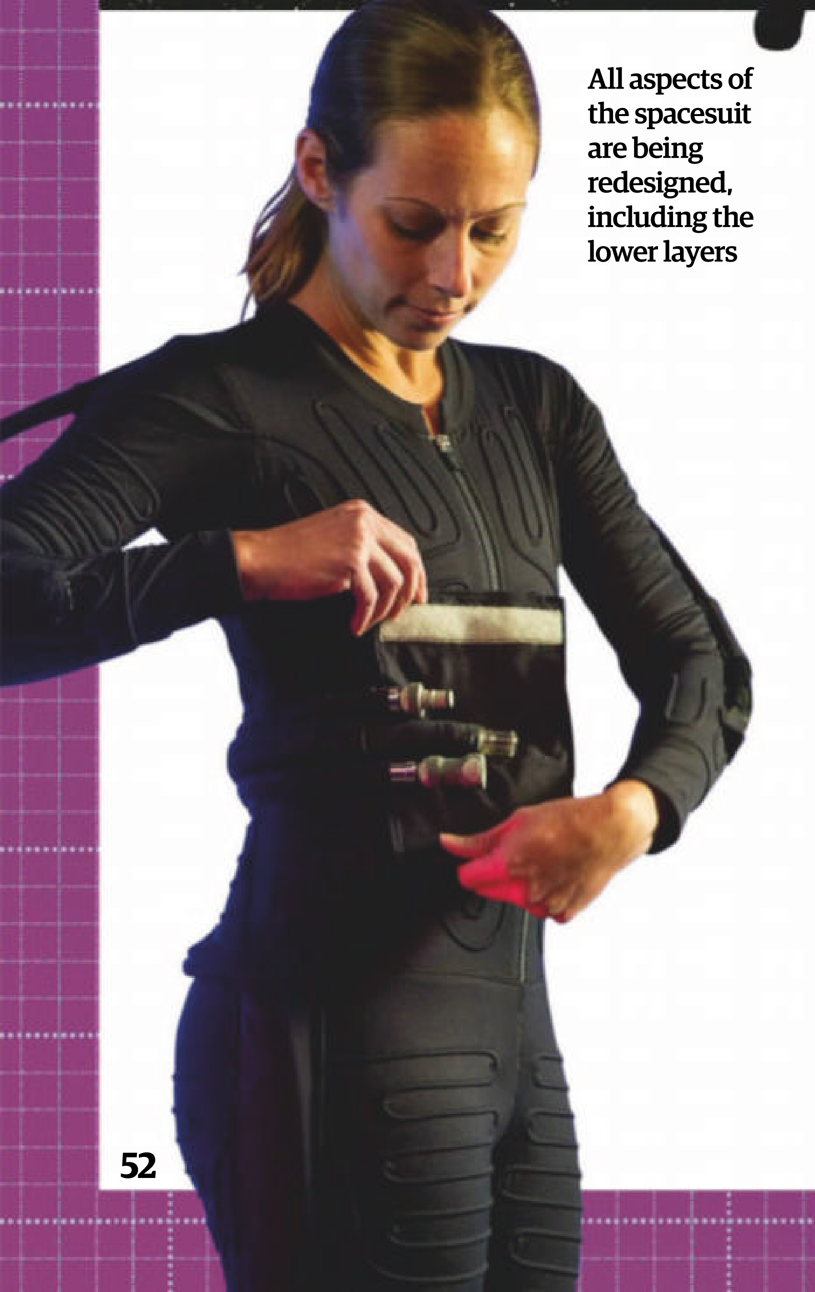
- ✓ **Full-pressure Intra Vehicular Activity safety garment**
- ✓ For use in high-altitude emergencies
- ✓ **Includes breathing oxygen and ventilation gas**
- ✓ Has parachute interfaces and communications
- ✓ **Lightweight and inexpensive**

SpaceX spacesuit

Name of space agency/private company: SpaceX

Key features

- ✓ **One-piece pressure suit entered via the inseam**
- ✓ Needed in case of in-flight emergency
- ✓ **White and black design**
- ✓ Tall boots and motorcycle-style helmet
- ✓ **Intended for use on Crew Dragon spacecraft**



All aspects of the spacesuit are being redesigned, including the lower layers

says astronauts will use this lunar-orbit space station as a staging post for exploration missions to Earth's natural satellite and eventually to the Red Planet. They'll travel there on the Orion spacecraft and will need suitable protection both inside and outside the craft.

"An astronaut that lands on the Moon will carry out spacewalks, conduct geology in the field, deploy science experiments, collect and analyse samples, prepare samples for Earth return, report observations to Earth and drive lunar rovers," Madill says. Since humanity's next destination on the Moon will be the extreme and alien landscape of the lunar south pole where temperatures as low as -238 degrees Celsius (-396 degrees Fahrenheit) have been recorded, the suit they wear will need to withstand the harsh conditions.

As such, designing a spacesuit, Madill says, has to draw on multiple skills. It requires knowledge of textiles, engineering, material science and atmospheric science all rolled into one. "Right now astronauts going to the ISS have a specialised spacesuit geared for spacewalks in low-Earth orbit," she continues. "But different suits will be needed if we want to go to the Moon, and they'll have to be tailored to the lunar environment." Spacesuits also need to take into account internal danger.

"One big difficulty is that they must operate with pure oxygen inside, which means that everything is flammable and highly corrosive," Southern says. "This makes electronics, which are critical for system operations, problematic. They must have a liquid-cooling garment, a pressure garment, a thermal garment, a micrometeoroid garment and an outer garment in addition to other layers."

NASA has also been working on a rear-entry technology demonstrator suit called the Prototype eXploration Suit (PXS) which focuses on improving suit fit and performance while cutting the amount of equipment that is needed for long-duration missions. Uniquely, it has 3D-printable components which could be created during missions to suit different requirements on the fly.

"This suit could be used for EVAs in microgravity or it could be further modified for walking on planets," Madill says. "The spacesuit has a Suit Control Assembly, which is a box at the front of the suit allowing the crew member to control certain life-support components including pressure and cooling and electronics (radio, volume). The astronaut also has an insight into some of the data that's coming back and forth from the suit computer to the display. The suit designers are currently wearing and using the suit to see what

the limitations are and incorporating changes that need to be made into the next prototype."

As we've mentioned, EVA suits are not the only ones being looked at: IVA suits are also being redesigned as part of an ongoing process, and this has led to innovations such as the xEMU-Lite, which is earmarked for possible testing on the ISS by the mid-2020s. Intended as a replacement for the current EMUs, they'll be vital if the space station's life is extended to the late 2020s. But they're not the only ones under development.

The Orion Crew Survival Systems Suit is being designed for use in the next-generation human spacecraft Orion, which aims to take humans farther than they have ever been before, and it's going to be equipped with a built-in toilet. This would come in handy if the spacecraft capsule depressurised, allowing the astronauts to remain in their suits for up to six days.

NASA is heavily involved in its creation, and yet private companies such as Final Frontier Design, SpaceX and Boeing are also coming into their own with regards to IVAs. Boeing, for example, tells us that it has eschewed the existing ACES suits for its Starliner spacecraft because it wanted a high level of compatibility between the suit and capsule. The new spacesuit offers greater pressurised mobility, lighter weights, touchscreen-friendly gloves and easy transitions from sitting to standing.

"These features improve human capability and performance and ensure mission success while working in the Starliner," says Boeing engineer Kavya Manyapu. "They're especially important during emergency situations when astronauts would have to perform critical functions.

"We wanted a suit that enhances their abilities, rather than impedes their ability to perform required actions. Examples include reaching and pulling the abort handle if an abort is necessary or reaching and opening oxygen valves from within their pressurised suit in the event of a cabin depressurisation. Additionally, in high-G environments, the lighter the suit the better it is."

Even so, ACES is not being entirely abandoned. As Madill tells us, NASA is considering making a few tweaks in order to create the Modified Advanced Crew Escape Suit (MACES). "It would provide contingency EVA capability to all Orion missions with mobility enhancements added to the former Shuttle ACES suit," Madill says. "MACES, however, has potentially limited mobility, which could increase crew fatigue and EVA task capability when they're using the suit."

Such negatives are not unusual, and it's fair to say there will never be a perfect spacesuit. Of course, there is a list of desires - "NASA really wants to see much more visibility, better mobility and better control and communications in their next-

> "We wanted a suit that enhances abilities, rather than impedes the ability to perform required actions" **Kavya Manyapu**

Above: The EMU cannot fit smaller astronauts, but the PXS is being designed with different sizes

Top centre: Vinita Marwaha Madill is involved in spacesuit design for the ESA

Right: Rear view of the PXS which shows how an astronaut fits snug inside

WHAT THE ASTRONAUTS THOUGHT

Nobody knows the existing suits better than the astronauts who have worn them

"If you want to squeeze your hand in a spacesuit, you're fighting the pressure of the suit itself. You can't turn your head because it's inside a helmet"
Chris Hadfield, Expedition 34/35

"The gloves are really tailored to the astronaut's hands, and it's very important because we need to do tasks which require a lot of fidelity"
Tim Peake, Expedition 46/47

"The spacesuit can be very difficult to manoeuvre – it feels like you're operating this machine, like it's your own little human-shaped spacecraft"
Jenni Sidey-Gibbons, astronaut-in-training

"NASA's suits were not very close-fitting, so once you inflated the suit it really made it much more difficult to operate"
Timothy Kopra, Expedition 20

© NASA; Final Frontier Design; Boeing; ROBYN BECK/AFP/Getty Images

Boeing's new Starliner suit being worn inside a mockup Starliner spacecraft

The PXS offers far greater flexibility and rotation than the current EMU suits

© NASA; Boeing

> "The 1960s and 1970s were an incredible era for space exploration; we haven't actually stepped foot on the Moon for a long 45 years" **Vinita Marwaha Madill**

generation space suit," says Madill - but a 'one-suit-suits-all' solution is clearly 'pie-in-the-sky' thinking.

"Engineering involves trade-offs, and there are some serious limitations to materials that make the perfect suit impossible," explains Southern. "The extreme environment of space is essentially impossible to safely protect a human against."

He says an ideal suit might be very lightweight, non-restrictive in mobility, highly reliable in terms of life support, inexpensive, thin and not bulky and have a very long life. But the best way forward, he contends, is to have different suits for different occasions, something Madill fully agrees with.

"The design of a spacesuit may seem simple since they are covered with a fabric thermal micrometeoroid garment, but it is in fact one of the most complex technological developments to carry out," Madill concludes. "Suits of the future need to use new ideas and some new materials to keep us on our way to the Moon and, later, Mars - similar to the new suits by SpaceX and Boeing that will be worn by astronauts inside their capsules as they launch to the International Space Station over the coming year."

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Asteroid Profile

Bennu

OSIRIS-REx is bringing more details of this space rock to the forefront of science

Asteroids may not seem special at first thought. There are so many of these chunks of rock scattered throughout the Solar System that one may not seem too big a deal. But, like so many small bodies throughout the universe, there is so much more than meets the eye. These ancient remnants can tell astronomers what the early Solar System was like when it was formed around 4.6 billion years ago.

Asteroid 101955 Bennu was discovered on 11 September 1999 as part of the LINEAR Project, a collaborative effort between NASA, the United States Air Force and the Massachusetts Institute of Technology's (MIT) Lincoln Laboratory for tracking near-Earth objects (NEOs). Bennu was one of many objects to make this list as it makes its closest approach to Earth every six years, coming roughly within about 300,000 kilometres (186,000 miles) from Earth, which is even closer than the Moon. It makes one orbit around the Sun every 1.2 years, making its orbit almost Earth-like.

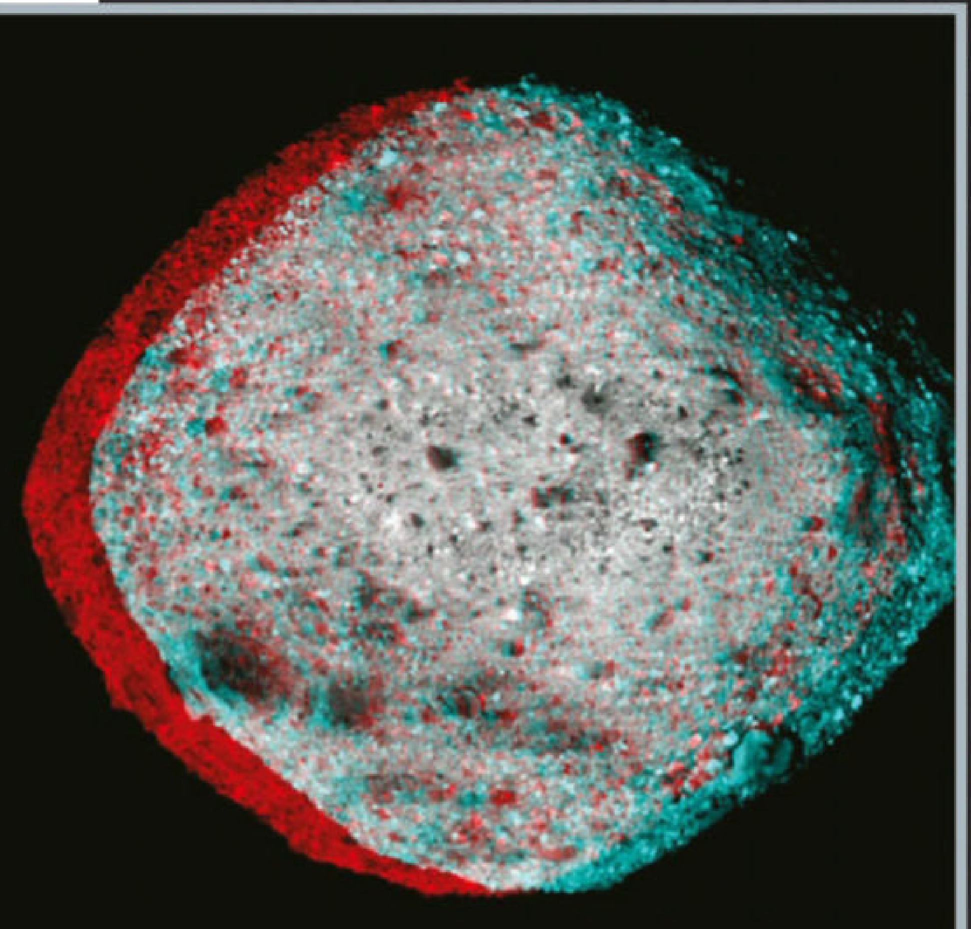
In terms of size, Bennu would be considered huge if it was to be placed on Earth. Having a diameter of 492 metres (1,614 feet), it is taller than the Empire State Building in New York, United States, and the Eiffel Tower in Paris, France. Its composition and material are currently a mystery, however – as it is such a small object in comparison to the planets it's hard to get any distinct visual observations on it. NASA's Spitzer Space Telescope managed to use its infrared-spying abilities to provide a diameter measurement, a low albedo reading and found the thermal inertia (heat transfer) to vary with each rotational period, which takes 4.3 hours. The analysis of this data also revealed that the regolith grain size is quite moderate, ranging from millimetres to centimetres, and evenly distributed.

Based on spectroscopic analysis astronomers have determined that Bennu is a B-type asteroid. This is a rare type of carbonaceous asteroid that could hold some exotic molecules formed over 4 billion years ago. The primitive composition of Bennu could reveal organic molecules, volatiles and amino acids that could have even brought life to Earth. Or, looking even further back in time, did the materials that led to our current Solar System stem from a distant supernovae? These answers may have been preserved in the frozen vacuum of space and haven't been tainted by the interference of our planet's atmosphere and environment before it could impact Earth. It's only by getting a sample of this unique, nearby asteroid that these answers can be truly put under the microscope, and that is exactly why NASA has sent the Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explore, abbreviated to OSIRIS-REx, spacecraft to investigate further.

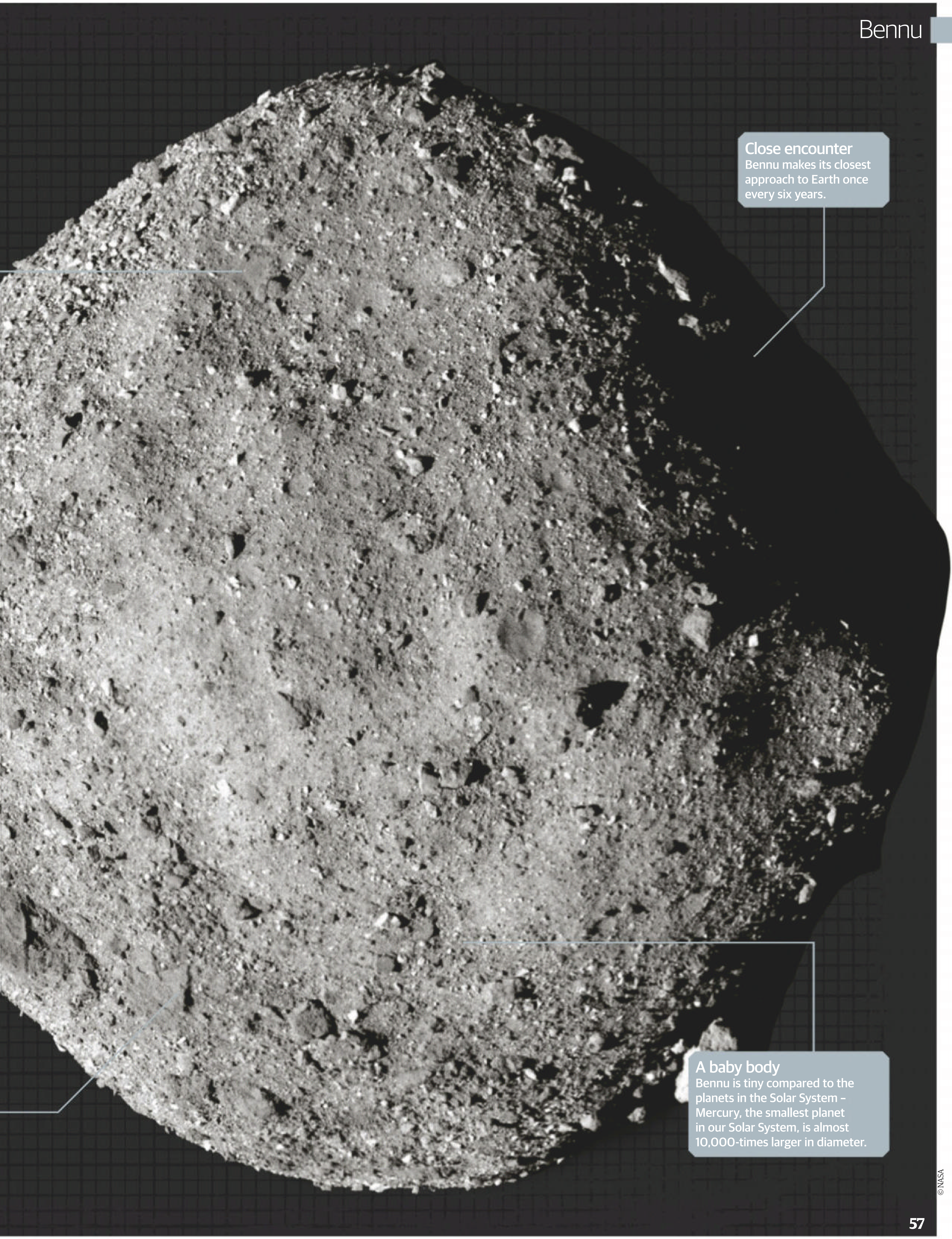
> "The primitive composition of Bennu could reveal organic molecules"

Asteroid origins
It's believed Bennu was formed at the same time as the rest of the Solar System some 4.6 billion years ago.

Peculiar shape
Bennu is shaped like a spinning top – a shape that astronomers are finding it hard to account for.



Images of Bennu have been given a 3D effect with the help of red/blue glasses

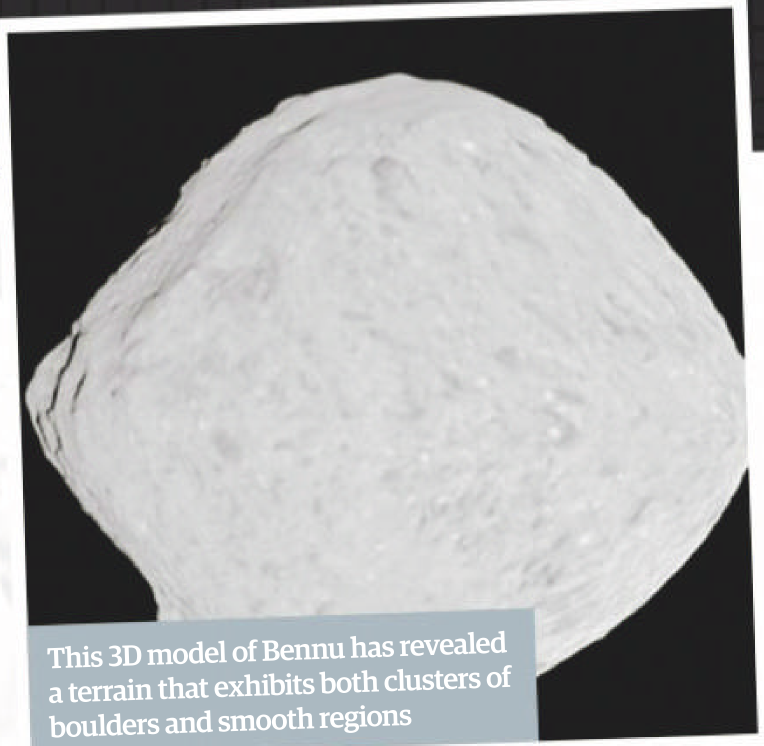


Close encounter
Bennu makes its closest approach to Earth once every six years.

A baby body
Bennu is tiny compared to the planets in the Solar System – Mercury, the smallest planet in our Solar System, is almost 10,000-times larger in diameter.

© NASA

Bennu catch-up

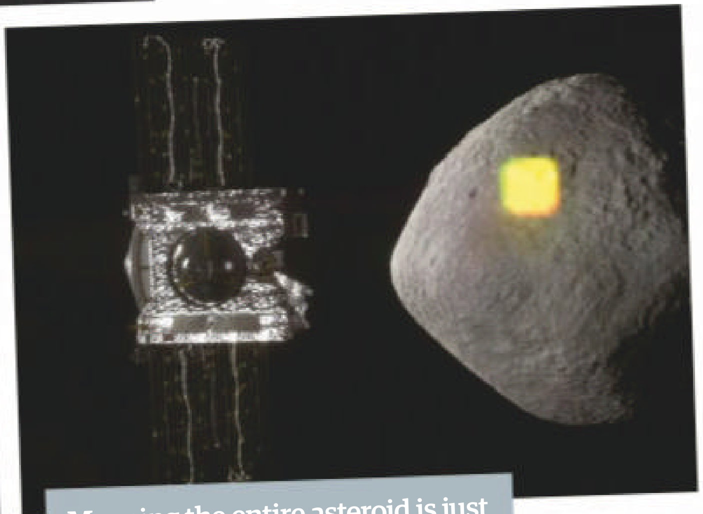


This 3D model of Bennu has revealed a terrain that exhibits both clusters of boulders and smooth regions

Bennu's welcoming shot

After a two-year, 2.2-million-kilometre (1.4-million-mile) journey, OSIRIS-REx was finally making its highly anticipated approach to Bennu. On 2 December 2018, on its approach, the spacecraft put its 20-centimetre (eight-inch) PolyCam to work in photographing Bennu in fantastic detail. The result was a beautiful mosaic image consisting of 12 images taken from just 24 kilometres (15 miles) away.

Using the same images astronomers were also able to construct a 3D model of the asteroid, demonstrating features as small as six metres (20 feet). The observations and model confirmed many aspects about the then-mysterious ball of rock that astronomers predicted, such as its shape, diameter, rotation speed and inclination. The only outlier was a large boulder near the south pole of the asteroid. The ground-based model suggested the boulder would be 10 metres (33 feet) in height, but up-close observations showed it to be closer to 50-metres (164-feet) high, with a width of approximately 55 metres (180 feet).



Mapping the entire asteroid is just one of the main scientific goals

Another source of water found

OSIRIS-REx is already making fascinating discoveries about Bennu – and it hasn't even collected a sample yet! The first major discovery from this mission was made by two of its instruments, the OSIRIS-REx Visible and Infrared Spectrometer (OVIRS) and the OSIRIS-REx Thermal Emission Spectrometer (OTES). These instruments revealed the presence of water inside the clays that make up the asteroid. These 'hydroxyls', which are molecules containing hydrogen and oxygen, exist over the entire asteroid and could hold important clues about the origins of Earth's water.

"The presence of hydrated minerals across the asteroid confirms that Bennu, a remnant from early in the formation of the Solar System, is an excellent specimen for the OSIRIS-REx mission to study the composition of primitive volatiles and organics," says Amy Simon, OVIRS deputy instrument scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, United States. "When samples of this material are returned by the mission to Earth in 2023, scientists will receive a treasure trove of new information about the history and evolution of our Solar System."

Improving asteroid tracking with OSIRIS-REx

When OSIRIS-REx made its approach in early December 2018, this began a near two-year, close-up adventure to find out what this intriguing asteroid has to offer. On its approach NASA compiled a manifesto to explain the importance of the OSIRIS-REx mission. It aim to understand the forces that move asteroids, help in detecting hazardous objects and improve predictions of any potential collisions.

As Bennu is about half a kilometre (a third of a mile) wide, Bennu is large enough to potentially reach the surface of the Earth and cause widespread damage. These observations will keep track of the asteroid's location to within a few kilometres.

Scientists have found it hard to estimate its future trajectory around the Sun due to the gravitational interference of Earth, the Sun and other objects. This is why predictions for Bennu's trajectory get fuzzy around 2060. "There are a lot of factors that might affect the predictability of Bennu's trajectory in the future, but most of them are relatively small," says William Bottke, an asteroid expert at the Southwest Research Institute in Boulder, Colorado, United States, and a participating scientist on the OSIRIS-REx mission. "The one that's most sizeable is Yarkovsky."

These are just a few benefits of asteroid examination that will benefit our understanding of asteroids in a scientific sense and in a tracking sense.

> "Scientists will receive a treasure trove of new information about the history and evolution of our Solar System"

OSIRIS-REx will contact Bennu with the Touch-And-Go Sample Arm Mechanism, or TAGSAM

Mission to Bennu

Bennu was unexplored and underappreciated before NASA's OSIRIS-REx arrived. No one even knew what it looked like, and it was merely referred to as 1999 RQ36! Now the finely tuned machine of instruments will map the entire asteroid and collect at least 60 grams (2.1 ounces) of its surface to bring back to Earth for analysis. This mission began on 8 September 2016 when the spacecraft was launched aboard an Atlas V rocket from Cape Canaveral, Florida, United States.

The OSIRIS-REx spacecraft includes the best cameras, altimeters and spectrometers that NASA could offer during construction. There are three cameras in the OSIRIS-REx Camera Suite (OCAMS): PolyCam, MapCam and SamCam. The OCAMS will be fundamental in mapping Bennu's surface and recording the touch-and-go manoeuvre. The Laser Altimeter (OLA) will use lasers to measure the distance from the asteroid for topographic measurements. The Thermal Emission Spectrometer (OTES), Visible and Infrared Spectrometer (OVIRS) and Regolith X-ray Imaging Spectrometer (REXIS) will identify the minerals present in different wavelengths, and determine the elements present on Bennu's surface.

The spacecraft also has two instruments that will orchestrate the landing, sample collection and return of the carbonaceous asteroid. The Touch-And-Go Sample Acquisition Mechanism (TAGSAM) is a sample head fitted at the end of an articulated arm. The Sample Return Capsule (SRC) is an aeroshell container that will survive the descent through the Earth's atmosphere to keep the sample safe for the scientists – once they find it!

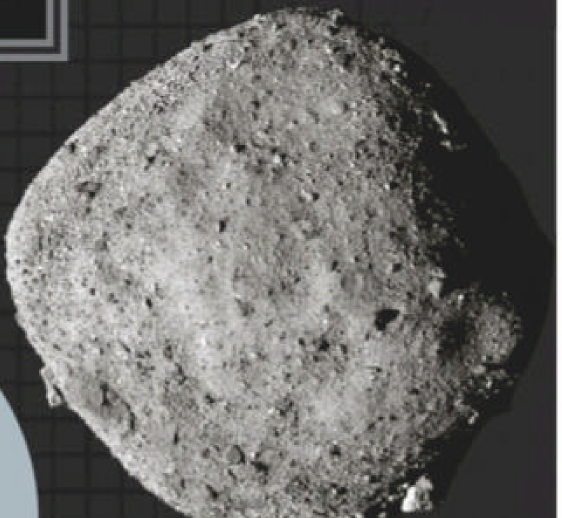
At the beginning of December 2018 OSIRIS-REx began its long-awaited approach to the asteroid, defining its shape and orbit. During New Year Eve celebrations on Earth OSIRIS-REx entered orbit around the asteroid, sitting at a distance of just 1.4 kilometres (0.9 miles) away.

OSIRIS-REx will help scientists investigate how the planets and the Sun were formed

Timeline of OSIRIS-REx at Bennu

- **Date:** 8 September 2016
  Activity: Launch from Cape Canaveral, Florida, United States, on an Atlas V 411 rocket.
- **Date:** 3 December 2018
  Activity: OSIRIS-REx arrives at asteroid Bennu, beginning the two-year survey.
- **Date:** 4 July 2020
  Activity: The spacecraft will make its descent to the asteroid; its main aim is to collect a sample of regolith.
- **Date:** 3 March 2021
  Activity: It will be time to call an end to the visit and OSIRIS-REx will depart Bennu and head back to Earth.
- **Date:** 24 September 2023
  Activity: The spacecraft will jettison the sample return capsule, and after reentry it will deploy a parachute, bringing the capsule in for a soft landing in the Utah desert.

Bennu's facts and stats



7,000

Bennu was chosen out of over 7,000 known NEOs to be the subject of OSIRIS-REx's investigation.

Bennu's close encounters to Earth give it a high probability of impacting Earth in the late 22nd century.

700 million to 2 billion

Bennu may have been a part of a larger carbon-rich asteroid that was broken off 700 million to 2 billion years ago.

Observations revealed Bennu absorbs the Sun's radiation and then re-radiates it to give it a push, known as the Yarkovsky effect.

OSIRIS-REx made Bennu the smallest object ever to be orbited by a spacecraft and set the record for the closest orbit of a planetary body by a spacecraft.

B-type asteroids, the category of Bennu, could contain life-forming compounds that led to life on Earth.

Bennu is named after the Egyptian deity that is linked to the Sun, creation and rebirth, usually depicted as a grey heron.

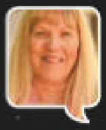
© NASA

MOONS

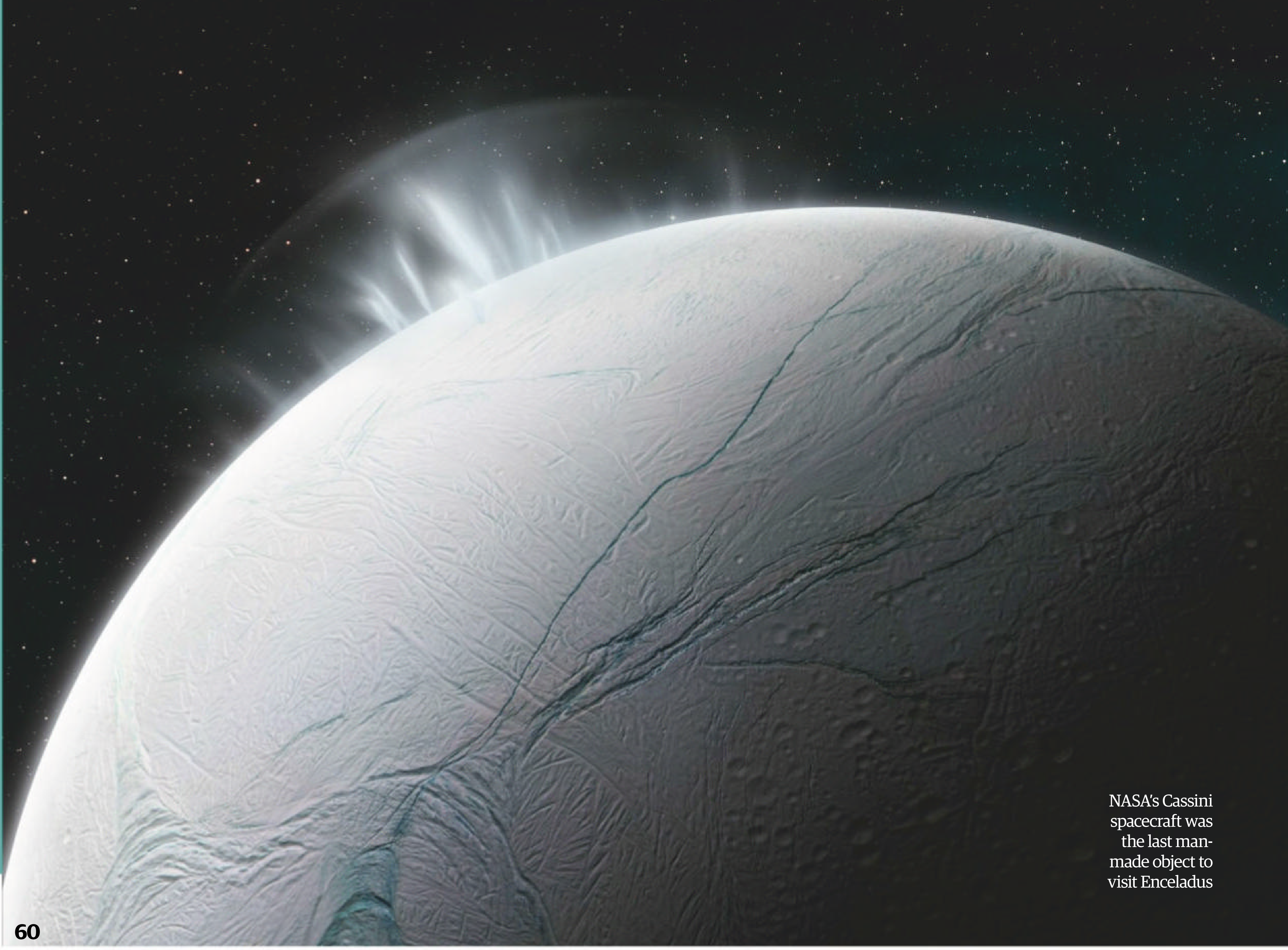
Why hasn't Enceladus frozen over yet?

NASA's Cassini spacecraft discovered that Enceladus, a small moon circling Saturn, has dozens of icy geysers erupting from cracks near its south pole that shoot plumes of mineral-laden water ice and water vapour into space. Cassini's science instruments also detected a global, salty ocean underneath Enceladus' icy crust that is the source of these geysers. This moon, only 480 kilometres (300 miles) across, is extremely cold and should have frozen solid long ago. However, something is keeping the ocean from freezing and turning Enceladus into a frozen ball of ice.

One explanation is that Enceladus' orbit is not a perfect circle, but is slightly eccentric, moving Enceladus closer to and farther from Saturn as it orbits the planet. This slight difference in distance to Saturn results in a tidal flexing of Enceladus, heating its interior. Perhaps the key to additional heat may lie in Enceladus' core. If this core is not solid, rocky material, but is instead porous, it could allow water to circulate through it. Tidal flexing could then cause rocky material to grind together, generating frictional heat that heats the water and creates hot spots on the ocean floor. All this excess heat helps maintain Enceladus' liquid-water ocean.



Linda Spilker is project scientist of NASA's Cassini mission that explored the Saturnian system



NASA's Cassini spacecraft was the last man-made object to visit Enceladus

ASTROPHYSICS

What's the importance of the Higgs Boson?

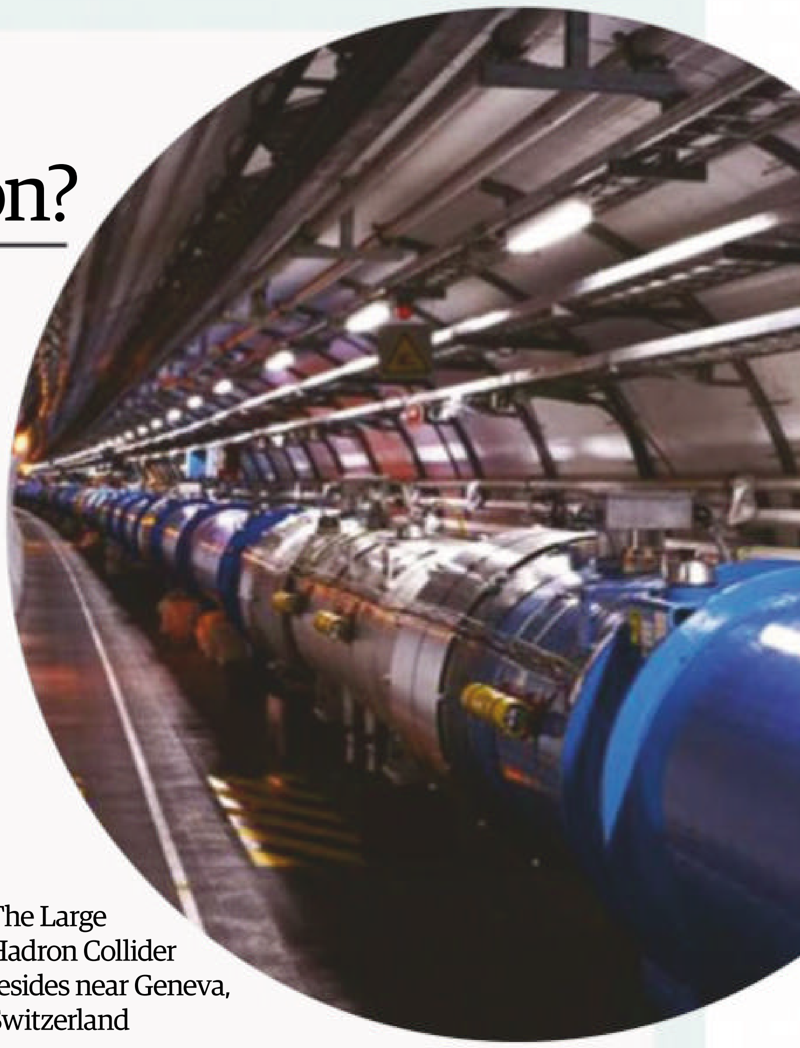
Within the Standard Model of particle physics the Higgs boson is the only fundamental particle without any intrinsic spin, allowing its interaction with itself and the other particles to generate the mass for other fundamental stuff like electrons and quarks.

Going beyond the Standard Model, the Higgs could hold the key to many important mysteries in particle physics. For example, the Higgs couples to vacuum fluctuations that should give it a mass near the Planck scale, where gravity becomes strong. Instead, the Higgs mass of 125 GeV (gigaelectronvolts) is 17 orders of magnitude smaller. We suspect that some as-yet-undiscovered physical mechanism is responsible. Popular candidates like simple supersymmetry or extra dimensions have not yet been discovered at the Large Hadron Collider.

These theories could produce unexpected LHC signatures such as neutral long-lived particles (LLPs) that are only visible once they decay to known particles. Luckily the LHC can search for these LLPs since they should occasionally be produced in exotic decays of the Higgs boson, and this possibility is coming under increased experimental scrutiny.

Finally, these theories could also leave their trace by modifying the cosmic microwave background or the distribution of dark matter in our Milky Way galaxy in subtle ways. The future of particle physics may lie at this interdisciplinary frontier, tying together the results from collider experiments with cosmological and astrophysical observations.

David Curtin is assistant professor at the Department of Physics, University of Toronto, Canada



The Large Hadron Collider resides near Geneva, Switzerland

> "Going beyond the Standard Model, the Higgs could hold the key to many important mysteries in particle physics"

ASTROPHYSICS

Why doesn't a supermassive black hole devour its entire galaxy?

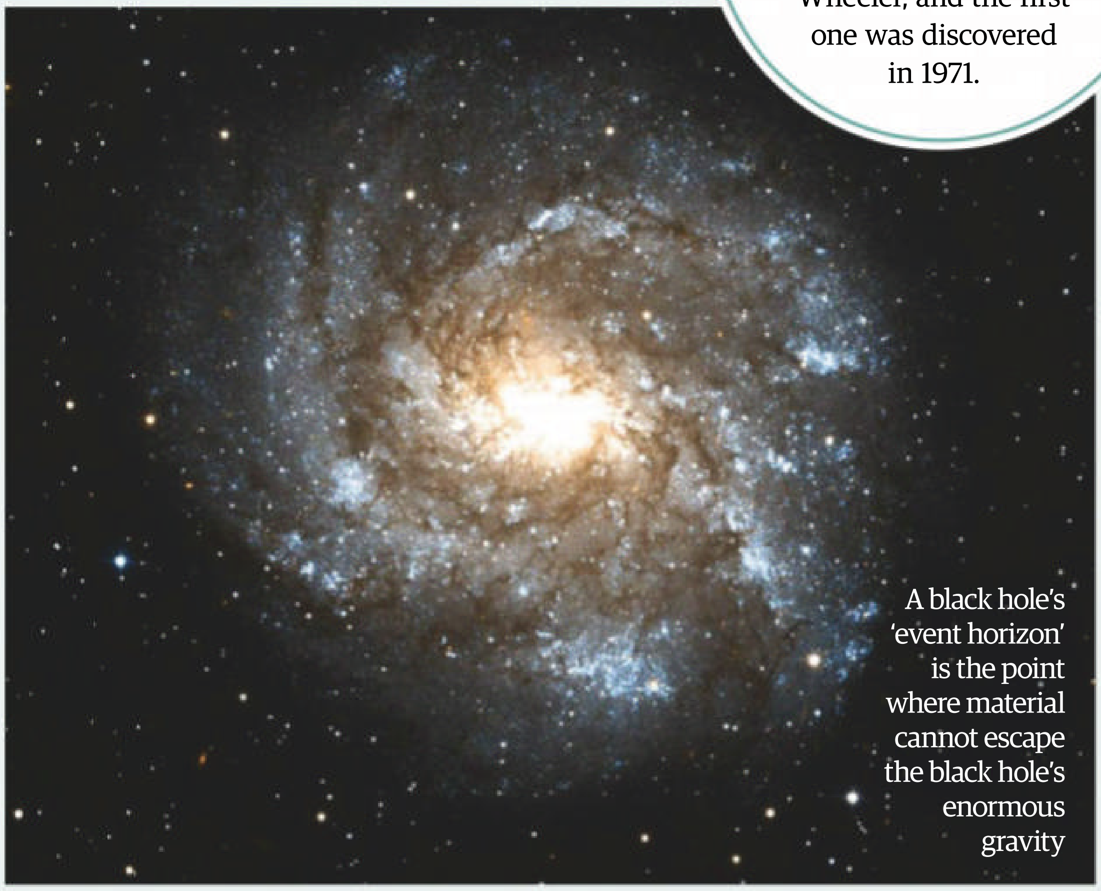
There are several factors working against the black hole sucking in all before it. The biggest one is probably the need to get material down into the centre before it can be eaten. Since the stars and gas in the galaxy are moving, either in circles in a galactic disc or in a wider range of different directions in an elliptical one, they typically have angular momentum, like a figure skater. If a skater brings in their arms, this quantity cannot be destroyed, and so they spin faster, making it tougher to bring their arms in further. The answer is not dissimilar to why all the bathwater doesn't disappear the moment you pull out the plug - first it has to spiral in and down.

Another factor is that the loss of angular momentum required to funnel matter into the very centre can be achieved by transferring energy and momentum outward as the material spirals in on progressively faster, tighter orbits. This is arranged by shearing between different layers. The stretched and sheared material can become hot enough that its radiation carries substantial momentum to the point where the push of this radiation can match the gravitational pull of the black hole, stopping the material from falling in. If the amount of matter falling in rises then the push rises in proportion, providing a feedback loop to slow the accretion of even the material that has made its way in close enough.

Andrew Blain is professor of Observational Astronomy at the University of Leicester, England

Did you know?

The term 'black hole' was first coined in 1967 by American astronomer John Wheeler, and the first one was discovered in 1971.



A black hole's 'event horizon' is the point where material cannot escape the black hole's enormous gravity

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PLANETS

Could there be any forms of life on Venus?

Liquid water is considered essential to any form of life as we know it, besides nutrients and a source of energy. All of these are found on Venus. Even though the lower atmosphere and the surface of Venus are quite hot, the cloud layer found between about 48 to 70 kilometres (30 to 44 miles) above the surface is much cooler, allowing the presence of liquid water. The clouds are made up of droplets of liquid sulphuric acid diluted with water, as well as other chemicals that can support life.

Being closer to the Sun, Venus receives more sunlight per unit area compared to Earth, but the present cloud cover reflects a large fraction back to space. The rest is scattered by the atmosphere and the clouds, a small fraction is absorbed and an even smaller amount reaches the surface. At shorter wavelengths the absorption by the clouds and atmosphere is somewhat greater due to the presence of unknown substances. It has been suggested that these could be colonies of microorganisms.

Life certainly could have evolved on Venus in its past when it had surface liquid water and migrated to the clouds, where it may be present today.

Sanjay Limaye is a senior scientist at the University of Wisconsin-Madison

The surface and clouds of Venus are much more tempestuous than Earth

Did you know?

The light released approximately 380,000 years after the Big Bang is known as the cosmic microwave background (CMB) and can be observed today.

After the Big Bang the universe had to expand before its first galaxies could form

ASTRONOMY

What is the farthest galaxy we know of?

The farthest galaxy currently known is called GN-z11 and is 13.4 billion light years away. The universe is estimated to be 13.7 billion years old, which means that this galaxy was formed within the first 300 million years of the universe, when the universe was in its infancy. At this time the universe was a hot and violent place, and its scale was much smaller than what it is today.

The stars in this early galaxy were 100-times more massive than our Sun and appeared blue in colour. It is unlikely for planetary systems to have already formed around stars in this galaxy.

Studying distant galaxies tells us about the state of the universe when it was very young, and the galaxies that were forming in it at the time. Nearby galaxies like Andromeda are almost as old as our Milky Way, and to trace how galaxies like our Milky Way formed and evolved astronomers must study galaxies at increasingly large distances.

This is similar to a 70-year-old person looking at pictures from their childhood. Having a picture for every age during their lifetime will help observe changes in their appearance over time and understand how they aged.

Aayush Saxena is a postdoctoral researcher at Leiden Observatory in the Netherlands

SPACE EXPLORATION

What's it like spending a year in space?

With the usual six-month stay you can kind of see the end and you think, "Okay, I launched in October and I'm coming back in March; I can envision getting there." But when you launch in March and you're thinking about coming back the next March, it is not something that you can really comprehend. I think the perfect duration for a spaceflight is somewhere on the order of two-and-a-half to three months. When you get to [that stage] you think, "I've really been here for a long time." To know that you have nine months to go is kind of hard to get your head around. As far as coming back, I was kind of surprised [at] how I felt different physically than the last time with regards to muscle soreness and joint pain, and then there is the skin issue.

Scott Kelly is a former NASA astronaut

Kelly has spent a total of 520 days in space, including a year on the ISS

> "I think the perfect duration for a spaceflight is somewhere on the order of two-and-a-half to three months"

SPACE EXPLORATION

Could astronauts ever land on the surface of Mars' moon Phobos?

Not Phobos, because it doesn't have much gravity, so it wouldn't be practical to colonise. Popular opinion is that Phobos and Deimos are actually captured asteroids, so we could use them for other things instead of setting up a base. We could do Mars sample-return missions from either moon because there is debris from Mars on them. This is because over billions of years Mars shot up debris from the surface thanks to now-dormant or extinct volcanoes and meteorite impacts, so scientists think we could find samples of Mars on the surface of Phobos and Deimos, using robots to search for them.

Another reason scientists want to go to the moons is to better understand asteroids. One of the discussions we've had in the US for over a decade now is whether we should stop at an asteroid before going to Mars, and if you go to Phobos or Deimos you're killing two birds with one stone - they are asteroids where you can learn about both Mars and about small asteroidal bodies. To land a robot on Phobos you would need some kind of system of harpoons and drills like the lander on the Rosetta probe had and to do a lot of thruster moves as there isn't enough gravity to land like you would on Mars.

Chris Carberry is the executive director and co-founder of Explore Mars Inc, a non-profit organisation that was created to advance the goal of sending humans to Mars within the next two decades

Phobos orbits 6,000 kilometres (3,700 miles) from the Martian surface

© NASA / JPL Caltech ; Peter and Zabransky

A long way from home

New Horizons travelled a further 1.6 billion kilometres (a billion miles) beyond dwarf planet Pluto to take these images

THE ULTIMA INSPECTION OF THE KUIPER BELT

NASA's New Horizons flew past the Kuiper Belt Object, Ultima Thule, at the beginning of the New Year. But what has been learned from the highly anticipated flyby?

Reported by Lee Cavendish

31 December 2018 // 7:00pm UTC (2:00pm EST)

The New Horizons team prepares for approach

Before NASA's New Horizons spacecraft made its New Years approach to Ultima Thule, the very excited New Horizons team held a press briefing in order to educate on and emphasise the importance of this flyby.

From left to right we see Alan Stern, the principal investigator, of the Southwest Research Institute (SwRI) in San Antonio, Texas, US. Next along the line is Helene Winters, the project manager, of John Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, US. Then there's the navigation team lead, Fred Pelletier of KinetX, Inc. in Tempe, Arizona, US. Sitting on the right is SwRI's John Spencer, the mission's deputy project scientist.

© NASA

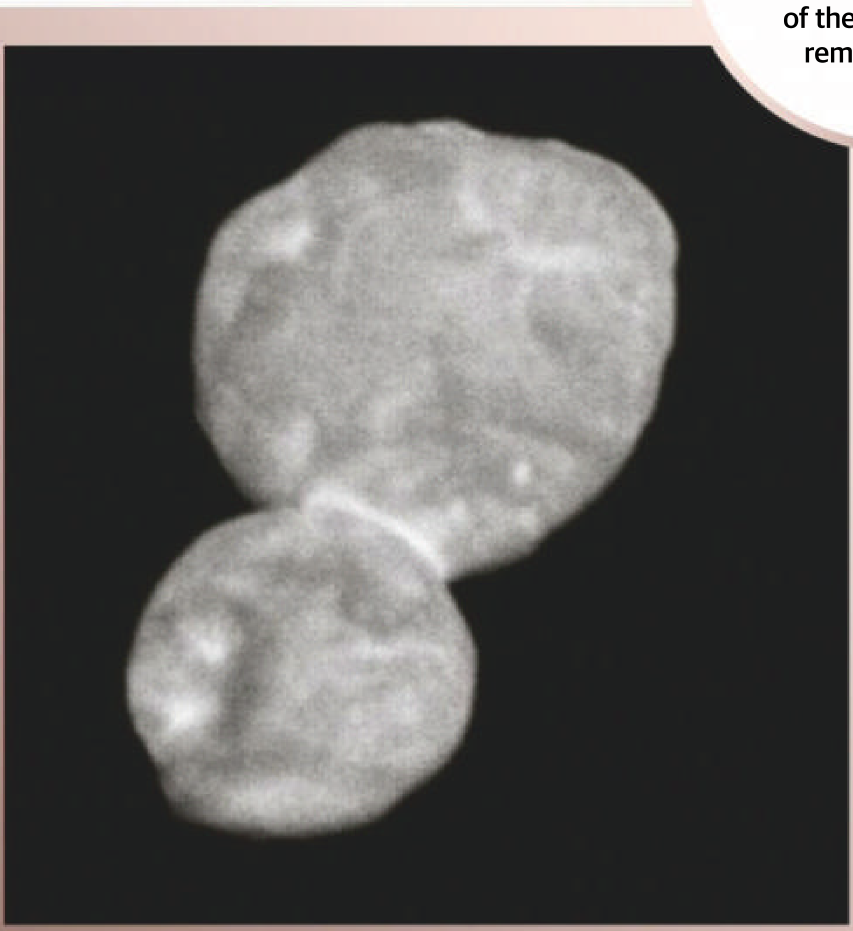
31 December 2018 // approx. 8:00pm UTC (3:00pm EST)

Rocking and rolling through the Solar System

The mission has grabbed the attention of many people worldwide, but a more recognisable name is Dr Brian May, guitarist of Queen and astrophysicist. During the press briefing May told the story of how Alan Stern had called him and asked him to make a song about the flyby of Ultima Thule.

May claimed that this was quite the challenge as he "[couldn't] think of anything that rhymes with Ultima Thule". But, lo and behold, Brian May got to work and created the song titled *New Horizons - Ultima Thule Mix*, inducting the mission into rock and roll fame as well as scientific fame.

Bucket loads of data
After a brief pause of data transmission in early January 2019, the spacecraft begins a 20-month download of the spacecraft's remaining data



1 January 2019 // 5:01am UTC (12:01am EST)

A whole new world

NASA's New Horizons flew past the Kuiper Belt object at approximate speeds of 14 kilometres per second (32,000 miles per hour), which is over 50-times faster than a Boeing 747 airplane. During the flyby the spacecraft's Long-Range Reconnaissance Imager (LORRI) got to work and revealed the intriguing and fascinating shape of Ultima Thule. This double-lobe shape – with one side larger than the other – and all its dents were imaged at a distance of 28,000 kilometres (18,000 miles). It appears that this is the first Kuiper Belt contact binary object to be observed.

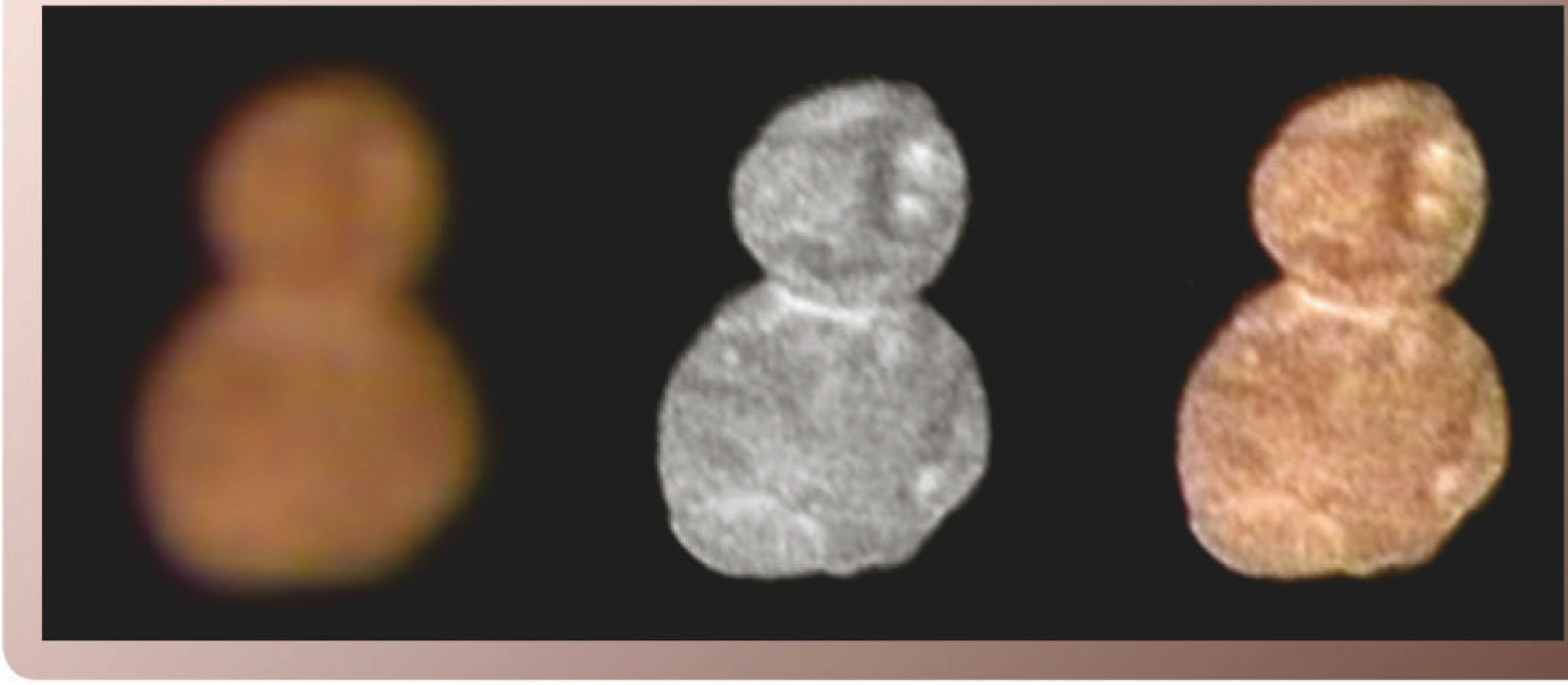
© NASA

1 January 2019 // 4:08am UTC (31 December 2018 // 11:08pm EST)

Enough of black and white

Black-and-white images of Ultima Thule do not reveal its true nature, but scientists were able to create the first true-colour images of the object using data taken by LORRI and the Multispectral Visible Imaging Camera (MVIC).

The left image is an enhanced-colour image taken by the MVIC shortly before its closest approach at a distance of 137,000 kilometres (85,000 miles). It combines near-infrared, red and blue channels. By combining this with LORRI's higher spatial resolution image (centre) the resulting image on the right shows Ultima Thule in a new light. Scientists are especially interested in the reduced red colouring at the neck of the object.

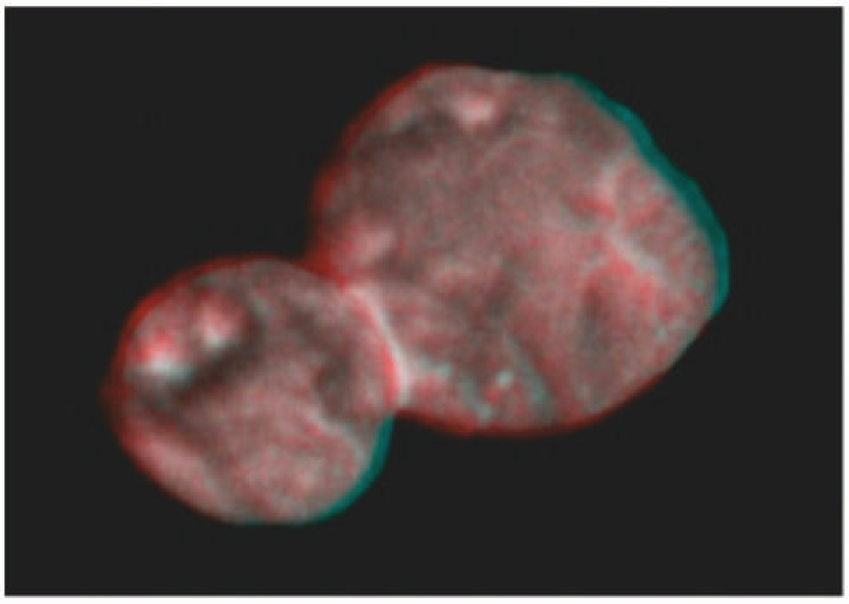


1 January 2019 // 4:23am UTC
(31 December 2018 // 11:23pm EST)

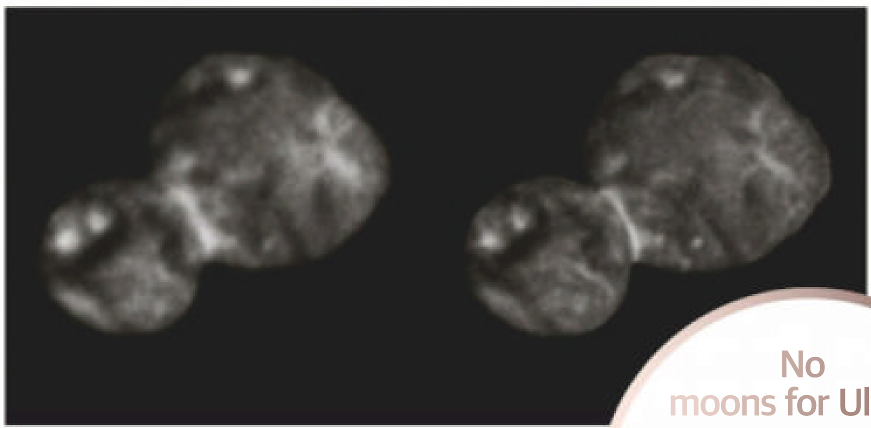
Three dimensions of Ultima Thule

Two images taken 38 minutes apart as the flyby took place, at ranges of 61,000 kilometres (38,000 miles) and 28,000 kilometres (17,000 miles) respectively, have been combined to create the first stereo image pair of Ultima Thule.

If you were wearing a pair of stereo glasses Ultima Thule would appear three dimensional, and some of its features would appear much more prominent. 'The first exploration of a small Kuiper Belt object and the most distant exploration of any world in history is now history, but almost all of the data analysis lies in the future," says Alan Stern.



> "Scientists were able to create the first true-colour images of the object"



1 January 2019 // 4:23am UTC
(31 December 2018 // 11:23pm EST)

Ultima caught spinning around

Using the same images that created the stereo image pair, scientists also created a GIF containing these two images of Ultima Thule. Although it may be hard to envision just looking at these two images on printed paper, by flicking between the two constantly the rotation of Ultima Thule is revealed, as well as some hints to the object's topography. The difference in brightness of the surface depressions between the two images provides scientists with hope as they have a thorough delve into the data collected by New Horizons. The animated GIF is available for all to see on the New Horizons website at **pluto.jhuapl.edu**.

No moons for Ultima

From the data already analysed, scientists can safely rule out any moons, satellites or rings larger than 1.6 kilometres (one mile) caught in Ultima's orbit

ASTRONOMY EXPERIENCE HOLIDAYS 2019

Whether it's aurorae, constellations, galaxies or a solar eclipse you're after, there are getaways to suit every astronomer all over the world

Tailor-made northern lights break

Location: *Muotka, Finland*
Company: *Aurora Zone*
Price: *£995 (approx. $1,255) per person*

The Northern Lights are one of the most beautiful astronomical sights around and, seeing the night sky light up in shades of green, purple and red never ceases to amaze. To lie on your back and watch energetic particles sent from the Sun excite the molecules in the upper atmosphere of Earth in a colourful display is breathtaking.

The Northern Lights, also known as Aurora Borealis, can be best seen from northern Europe and the Arctic Circle, and the Scandinavian countries are known for accommodating some of the best sights. The Muotkan Wilderness Lodge in Finland offers wonderful scenery from cabins among the trees.

Solar eclipse Chile explorer (2019)

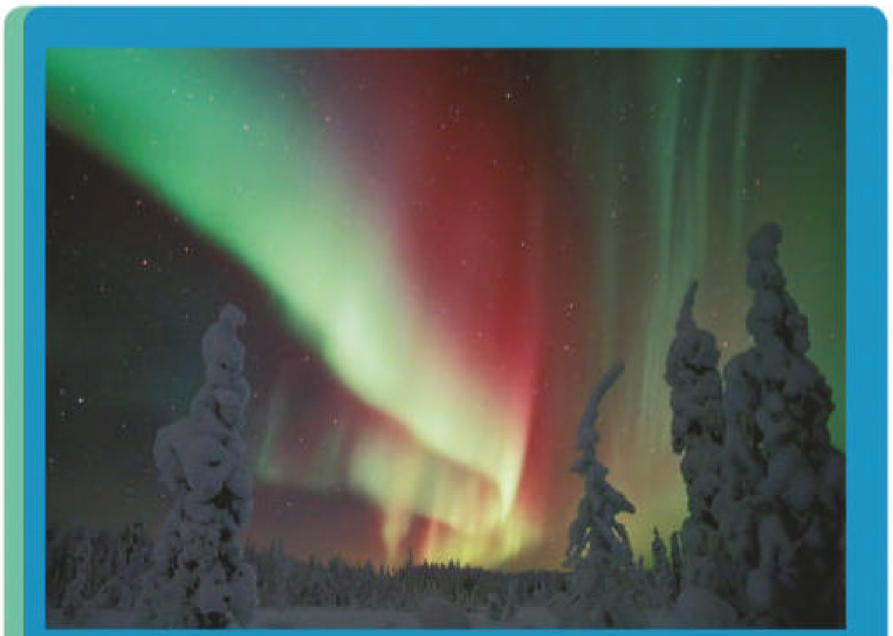
Location: *Santiago, Chile*
Company: *Grand American Adventures*
Price: *From £2,749 (approx. $3,470) per person*

On 2 July 2019 Chile will host an exciting solar eclipse, when the Moon passes in front of the Sun, and for two minutes and 18 seconds in the afternoon above Chile's Elqui Valley, our star will darken. For seven days you can enjoy the wonderful landscape, colourful culture and history of the Chilean capital. Although this is all a huge bonus to a holiday, the eclipse is what you come for, and this holiday package provides everything necessary to enjoy the tantalising totality.

Left: The Finnish experience can last for at least three days

Right: This five-day experience will show you the most beautiful sites of Iceland's capital

Below: The Chilean landscape is beautiful and will be complimented well by 2019's solar eclipse



Golden Circle and Northern Lights Inn

Location: *Reykjavik, Iceland*
Company: *Aurora Zone*
Price: *£1,225 (approx. $1,550) per person*

Another high-latitude country that is not only freezing cold, but also appropriately located to best observe the Northern Lights is Iceland. This geologically and volcanically active country just outside the Arctic Circle will bring a completely unforgettable experience.

If you aren't lucky enough to see the Northern Lights, this tour offers the chance to see the capital, Reykjavik, the famous 'Golden Circle' and Blue Lagoon. For four nights, it's an ideal trip for the avid Aurora Borealis chaser as you get the combination of comfortable accommodation whilst being away from light pollution.

© ESO; Sophia Groves / Getty; Finnish Tourist Board; Loop Images / Getty

A night of stargazing

Location: *Fuerteventura, Canary Islands*
Company: *Stars by Night*
Price: *From 23€ (£20) child, 33€ (£29) adult*

There is nothing like a cloudless, glistening sky away from the light pollution of cities. Looking up and seeing the incredible amount of stars twinkling, forming stellar patterns and hearing the mythical stories behind the constellations from an island surrounded by the Atlantic Ocean will leave many in extreme awe.

Stars by Night offers to collect you from your accommodation in Fuerteventura, Canary Islands to head to a dark-sky site where plenty of stargazing and astrophotography can be achieved.

Left: Weather permitting, the Milky Way can be seen with fantastic clarity

Top right: The Galloway Forest Dark Sky Park was the first Dark Sky Park in the UK and Europe

Middle right: The Brecon Beacon's high altitude and lack of light pollution makes for a rare clear sky in the UK

Bottom right: Solar activity will play a huge part in witnessing the dancing lights of the night sky

Visiting an observatory

Location: *Dalmellington, Scotland, United Kingdom*
Company: *Scottish Dark Sky Observatory*
Price: *£10 ($13) for children, £12 ($15) for students and 65+, £16 ($20) Adults, prices vary depending on the session*

The Scottish Dark Sky Observatory is a wonderful observatory open to the public, amateur astronomers, groups, clubs and anyone who fancies the trip! Even if the clouds have come out over the Galloway Forest Dark Sky Park there is still a mobile planetarium that can lead to a immersive experience of the night sky.

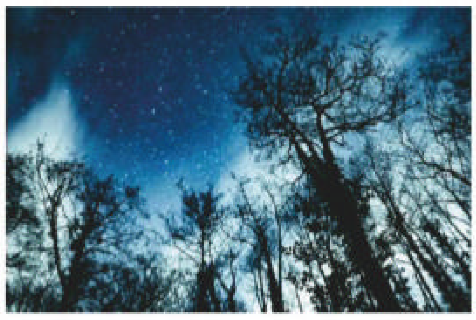
There are evening sessions that normally last for 90 minutes, group bookings for schools, clubs and societies and even telescope hire for the more seasoned astronomers. There are also special occasions where there is a particular astronomical event running or a special guest speaker - so be sure to look out for updates.

Stargazers' retreat

Location: *Brecon Beacons, Wales, United Kingdom*
Company: *Stargazers Retreat*
Price: *From £89 (approx. $113) per night*

The United Kingdom is home to some of the most jam-packed and light-polluted cities in the world. It's hard to find somewhere to escape just to enjoy the simple treasures the night sky has to offer.

The Stargazers Retreat offers a quaint cottage in the Brecon Beacons fitted with its own observatory and a computerised Meade telescope to observe the heavens in great detail. There is so much more to the Brecon Beacons than clear night skies, too, with a plethora of marvellous sights in the surrounding woodlands.



Southern escape

Location: *Tasmania, Australia*
Company: *TasVacations*
Price: *From AU $806 (approx. £640) per person*

There are fewer places to go in the Southern Hemisphere to see the Aurora Australis, also referred to as the Southern Lights. One location commonly visited by nature's light show is Tasmania. In a six-night escape provided by TasVacations, this tour will take you to three places in the south of the island state. Once away from the light pollution, the chance to observe the Southern Lights will be well worth the adventure.

A night at Pic du Midi

Location: *Pic du Midi, Hautes-Pyrénées, France*
Company: *Pic du Midi*
Price: *From 339€ (approx. £305) per person*

The beautiful Pic du Midi at the Grand Site of the Hautes-Pyrénées in France can take you above the clouds with its 2,877-metre (9,439-feet) elevation. At the summit is not only a wonderful landscape and view, but also the Pic du Midi Observatory. The unparalleled experience can have anyone marvelling at the sunset, as well as the stars above.

This observatory was completed in 1908 and has been used to discover nine minor planets using its array of telescopes. If you want to take a break indoors there is also a museum showing the history of men between the Earth and the stars.

A week-long astronomy holiday

Location: *Tenerife, Canary Islands*
Company: *Dark Skies Tenerife*
Price: *475€ (approx. £428) per person*

Tenerife is a popular holiday destination, with approximately five million tourists visiting it each year. Tourism company Dark Skies Tenerife offers astronomy lovers the only dedicated guest house on the island. Within this package are organised stargazing exercises and astronomy and astrophysics trips for beginners to the more experienced observers of the night sky.

The week-long holiday starts with being picked up from Tenerife south airport to your accommodation (which includes excellent meals), followed by tours of Tenerife Observatory along with exquisite sights of the night sky with a top-class telescope - inflatable stargazing pods are also included! At the end of the week, you will be driven back to the airport for your flight home.

Above: Pic du Midi is the only dark-sky reserve in France

Right: Norway is an excellent location to watch the Northern Lights as it is so close to the Arctic Circle

Below: Tenerife's tropical conditions allow for minimal cloud coverage and better viewing conditions

The astronomy voyage

Location: *Norwegian coast*
Company: *Hurtigruten LTD*
Price: *From £1,610 (aprrox. $2,043) per person*

For 12 days you can travel along the gorgeous coast of Norway, chasing down the Northern Lights from Bergen to Trondheim. The voyage will make stops at beautiful Norwegian towns and truly beautiful landscapes along the way, too.

Special lecturers in astronomy will educate you on the Northern Lights, the Arctic sky and the Solar System. There is also a visit to the Northern Lights Planetarium in wonderful Tromsø in northern Norway. Flights and transfers are not included in the package, but once aboard the cruise, you can put your feet up and enjoy the next 12 days.

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STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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Red light friendly

In order to preserve your night vision you should read our observing guide under red light

What's in the sky?

31 JAN
Conjunction between the Moon and Venus in Ophiuchus

31 JAN
The Moon and Venus make a close approach, passing within 0°05' of each other in Ophiuchus

31 JAN
The Beehive open star cluster (Messier 44) is well placed for observation in Cancer

2 FEB
Conjunction between the Moon and Saturn

5 FEB
Asteroid 532 Herculina reaches opposition, glowing at magnitude 8.9

8 FEB
Globular cluster NGC 2808 is well placed for observation in Carina at magnitude 6.2

18 FEB
Total lunar eclipse visible from Africa, Oceania, the Americas, Europe and Turkey

19 FEB
Conjunction between Mercury and Neptune in Aquarius

19 FEB
Bode's Galaxy (Messier 81) is well placed for observation in Ursa Major

26 FEB
Mercury is well placed for observation in the evening sky, shining at magnitude -0.5

26 FEB
Mercury is at greatest elongation east, shining brightly at magnitude -0.5 in the evening sky

27 FEB
Conjunction between the Moon and Jupiter in Ophiuchus

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

31 JAN

Omicron Velorum open star cluster (IC 2391) is well placed for observation in Vela

1 FEB

The Moon and Jupiter make a close approach, passing within 2°43' of each other in Ophiuchus

2 FEB

The Moon and Saturn make a close approach, passing within 0°37' of each other in Sagittarius

10 FEB

Conjunction between the Moon and Mars in Pisces

13 FEB

Mars and Uranus pass within 0°58' of each other in Aries

13 FEB

Conjunction between Mars and Uranus in Aries

21 FEB

Open star cluster NGC 3114 is well placed for observation in Carina at magnitude 4.2

© G Furtado

23 FEB

Conjunction between Venus and Pluto in Sagittarius

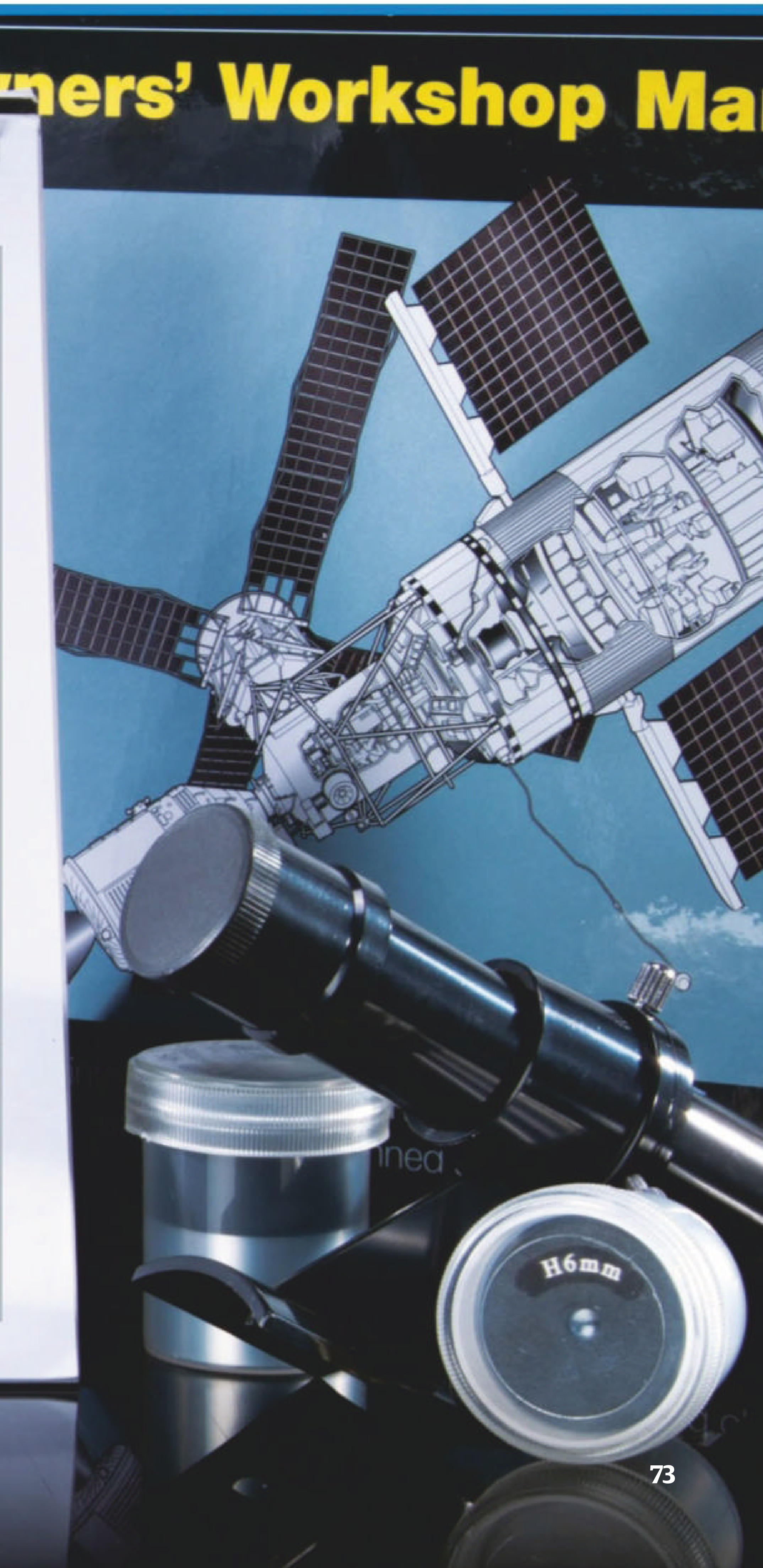
27 FEB

The Moon and Jupiter make a close approach, passing within 2°17 of each other in Ophiuchus

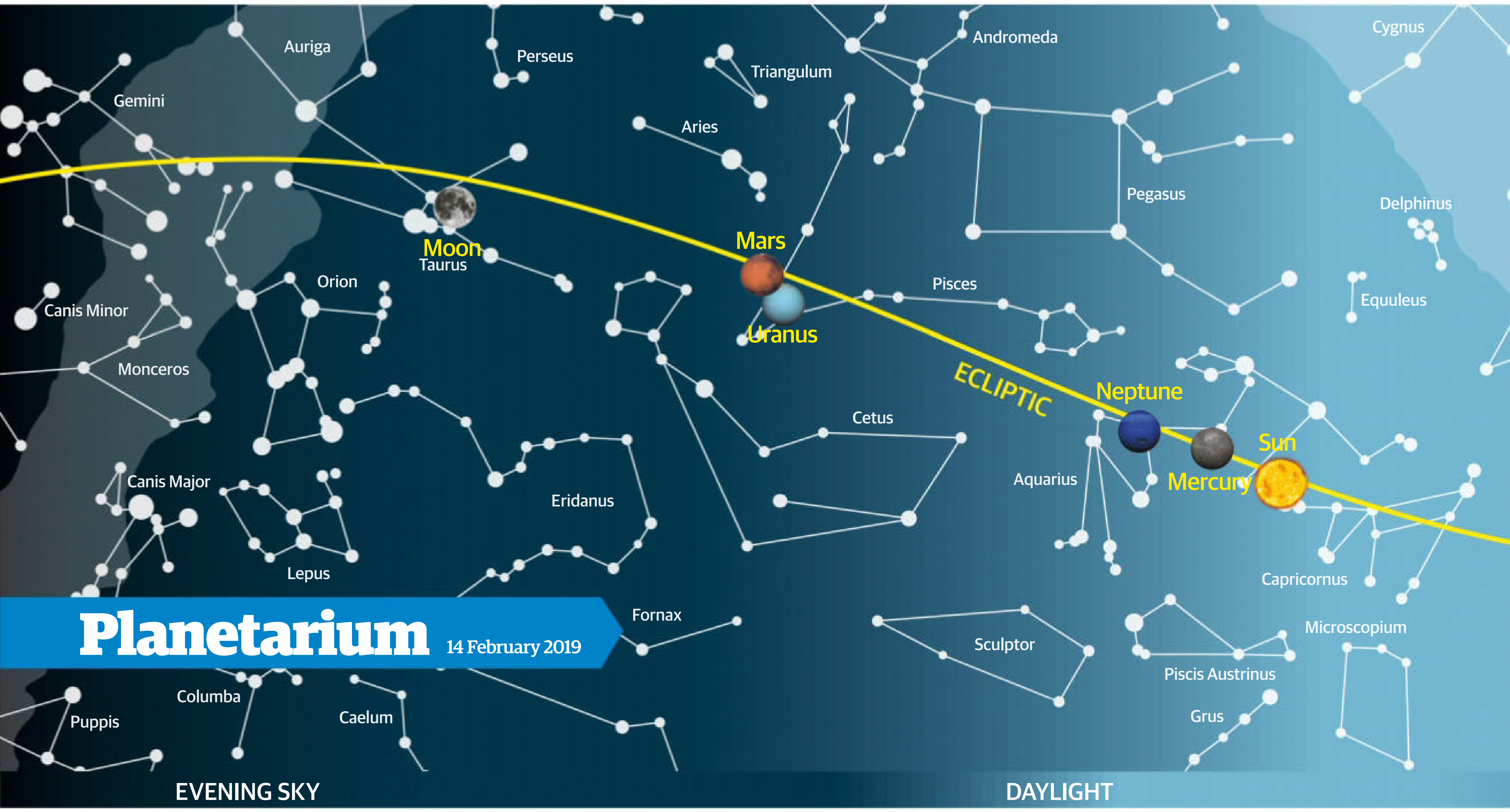
27 FEB

Open star cluster IC 2581 is well placed for observation in Carina, glowing at magnitude 4

Naked eye
Binoculars
Small telescope
Medium telescope
Large telescope



STARGAZER



Planetarium

14 February 2019

Moon calendar

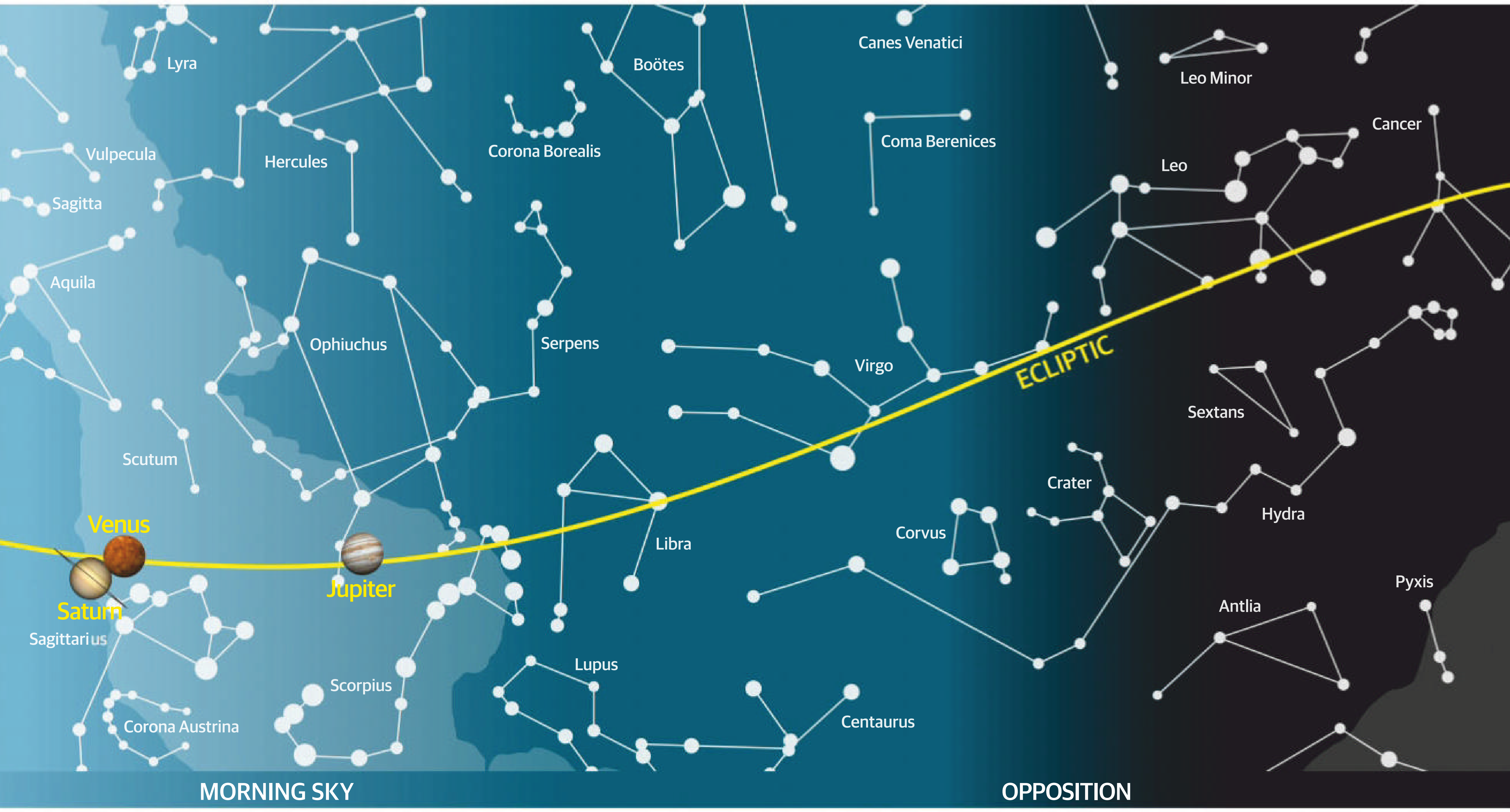
* The Moon does not pass meridian on 19 February

31	JAN		17.5%	▲04:24	▼13:00
1	FEB		10.6%	▲05:23	▼13:43
2	FEB		5.3%	▲06:15	▼14:33
3	FEB		1.8%	▲06:58	▼15:29
4	FEB	NM	0.1%	▲07:34	▼16:29
5	FEB		0.4%	▲08:05	▼17:32
6	FEB		2.6%	▲08:30	▼18:37
7	FEB		6.6%	▲08:52	▼19:42
8	FEB		12.2%	▲09:12	▼20:48
9	FEB		19.4%	▲09:31	▼21:54
10	FEB		29.0%	▲09:50	▼23:02
11	FEB		37.7%	▲10:11	▼--:--
12	FEB	FQ	48.1%	▼00:11	▲10:34
13	FEB		59.1%	▼01:22	▲11:02
14	FEB		69.9%	▼02:34	▲11:36
15	FEB		80.2%	▼03:46	▲12:21
16	FEB		89.0%	▼04:52	▲13:17
17	FEB		95.5%	▼05:51	▲14:26
18	FEB		99.3%	▼06:39	▲15:46
19	FEB	FM	--.-*%	▼07:18	▲17:11
20	FEB		99.7%	▼07:50	▲18:37
21	FEB		96.9%	▼08:17	▲20:01
22	FEB		91.2%	▼08:41	▲21:23
23	FEB		83.2%	▼09:05	▲22:41
24	FEB		73.6%	▼09:29	▲23:57
25	FEB		63.2%	▼09:55	▲--:--
26	FEB	LQ	52.5%	▲01:09	▼10:25
27	FEB		42.1%	▲02:17	▼10:59
28	FEB		32.3%	▲03:18	▼11:40

% Illumination
▲ Moonrise time
▼ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	7 FEB	14 FEB	21 FEB	28 FEB
MERCURY	100%	100%	70%	50%
VENUS	60%	70%	70%	70%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	31 Jan	20h 56m 56s	-19º 25’ 19”	Capricornus	-1.5	08:14	16:34
	07 Feb	21h 45m 55s	-15º 25’ 57”	Aquarius	-1.4	08:10	17:21
	14 Feb	22h 33m 27s	-10º 20’ 14”	Aquarius	-1.2	07:59	18:12
	21 Feb	23h 16m 03s	-04º 38’ 47”	Aquarius	-1.0	07:42	18:59
	28 Feb	23h 45m 39s	+00º 19’ 36”	Pisces	-0.4	07:17	19:28
VENUS	31 Jan	17h 39m 48s	-20º43’ 21”	Ophiuchus	-4.3	05:07	13:08
	07 Feb	18h 13m 54s	-21º 09’ 28”	Sagittarius	-4.2	05:17	13:11
	14 Feb	18h 48m 36s	-21º 09’ 02”	Sagittarius	-4.2	05:24	13:19
	21 Feb	19h 23m 33s	-20º 40’ 32”	Sagittarius	-4.1	05:28	13:29
	28 Feb	19h 58m 30s	-19º 43’ 44”	Sagittarius	-4.1	05:28	13:43
MARS	31 Jan	01h 13m 17s	+08º 03’ 30”	Pisces	0.9	09:51	23:28
	07 Feb	01h 30m 57s	+09º 55’ 17”	Pisces	0.9	09:31	23:29
	14 Feb	01h 48m 48s	+11º 43’ 06”	Aries	1.0	09:10	23:30
	21 Feb	02h 06m 51s	+13º 26’ 13”	Aries	1.1	08:50	23:31
	28 Feb	02h 25m 06s	+15º 03’ 56”	Aries	1.2	08:31	23:32
JUPITER	31 Jan	17h 05m 13s	-22º 12’ 59”	Ophiuchus	-1.9	04:43	12:23
	07 Feb	17h 10m 18s	-22º 19’ 21”	Ophiuchus	-1.9	04:22	11:59
	14 Feb	17h 15m 00s	-22º 24’ 39”	Ophiuchus	-2.0	04:00	11:36
	21 Feb	17h 19m 18s	-22º 28’ 59”	Ophiuchus	-2.0	03:37	11:12
	28 Feb	17h 23m 08s	-22º 32’ 28”	Ophiuchus	-2.1	03:14	10:48
SATURN	31 Jan	19h 03m 09s	-22º 11’ 17”	Sagittarius	0.6	06:41	14:20
	07 Feb	19h 06m 24s	-22º 06’ 36”	Sagittarius	0.6	06:16	13:57
	14 Feb	19h 09m 30s	-22º 01’ 54”	Sagittarius	0.6	05:51	13:33
	21 Feb	19h 12m 26s	-21º 57’ 14”	Sagittarius	0.6	05:26	13:09
	28 Feb	19h 15m 10s	-21º 52’ 42”	Sagittarius	0.6	05:00	12:45

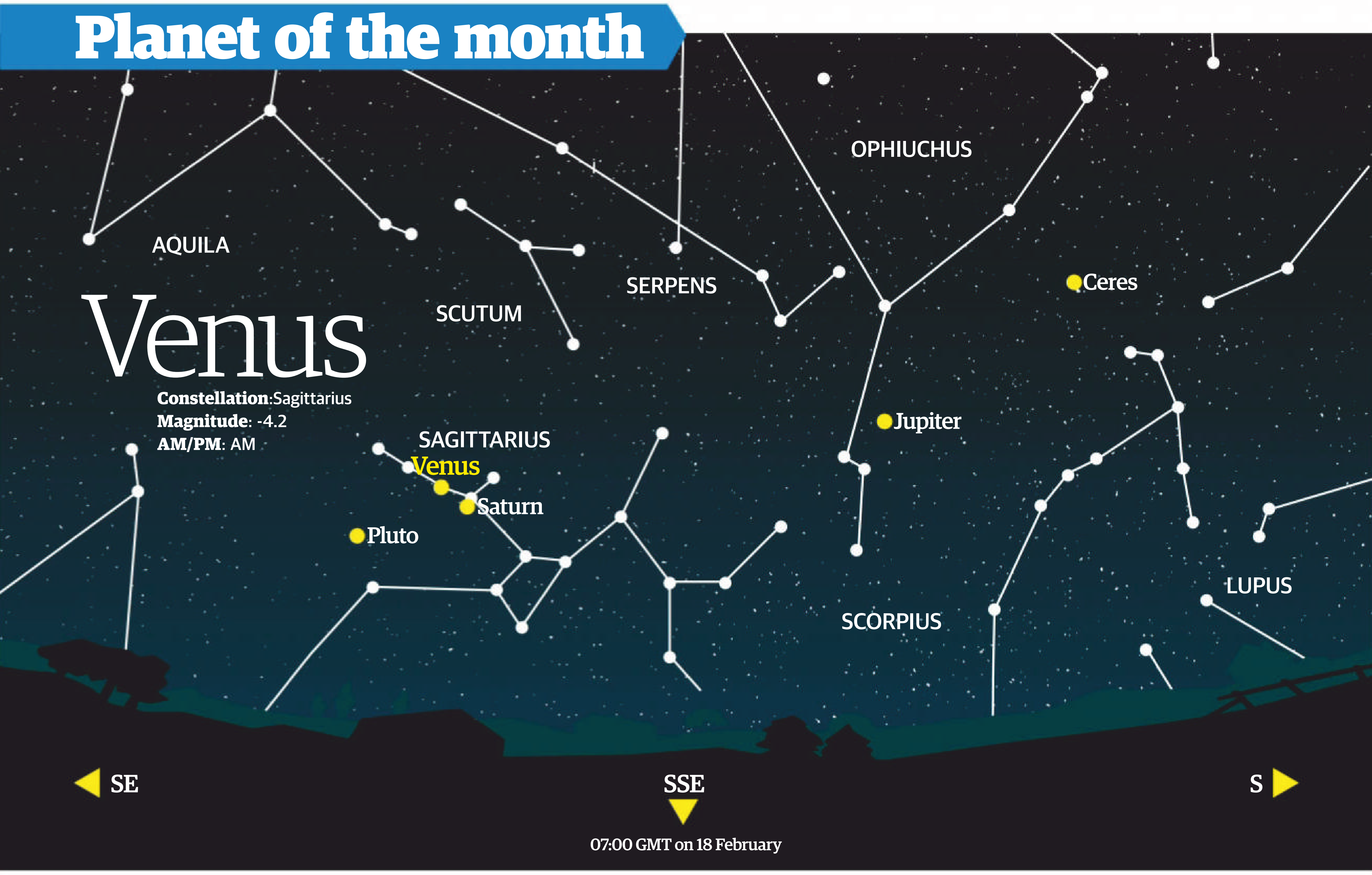
This month's planets

The sky truly belongs to Venus this month as it takes centre stage in the morning sky

Planet of the month

Venus

Constellation:Sagittarius
Magnitude: -4.2
AM/PM: AM



07:00 GMT on 18 February

Without a shadow of a doubt the February morning sky belongs to Venus. Go outside before sunrise on any crisp, chilly February morning and you'll see Venus blazing like a lantern in the southeast, looking like a piece of burning magnesium to the lower left of fainter, but still impressive Jupiter. It will be so striking you'll simply be unable to miss it. Looking at Venus on a still, dark morning you'll appreciate why it was named after the Roman Goddess of Love - the planet is such a stunning sight that it is hard to drag your eyes away from it; it almost hypnotises you…

However, Venus' lovely appearance is very deceptive. Often called 'Earth's Twin', Venus is similar to our own world in size only; in almost every other way it is a hell planet. Ironically it is that thick atmosphere which makes Venus such a stunning sight in our sky. It acts like a mirror, reflecting the Sun's rays back into space. So as you gaze lovingly at Venus this month, take a moment to reflect on the fact that you're staring across millions of kilometres of space at a world that is as alien and hostile to life as it is beautiful.

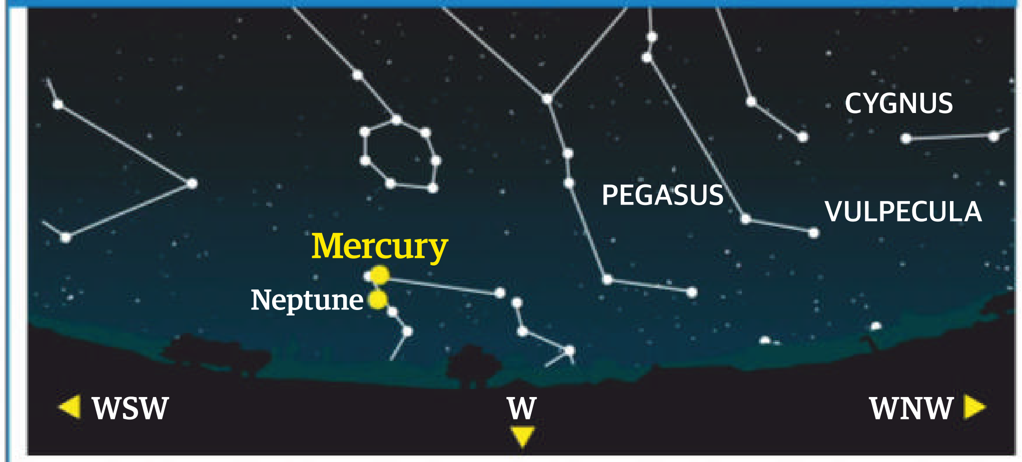
Venus will be at its best at the start of the month when it will rise two-and-a-half hours before the Sun, meaning we will be able to see it in a dark sky from around 5:00am. By month's end Venus will have moved closer to the Sun and will rise just an hour-and-a-half before it, reducing the time available for us to see it.

February will be a very social month for Venus. As well as keeping Jupiter company in the pre-dawn sky it will also be visited by Saturn and the Moon. On the morning of the 18th Venus and the Ringed Planet will be just a degree apart and will be a lovely sight through binoculars or a small telescope. Before sunrise on the 27th Venus will be on the end of a chain of worlds stretching from the southeast to the south, with Venus, Saturn, Jupiter and the waning crescent Moon all spread out across the sky in a celestial parade no self-respecting astrophotographer or planet-watcher will want to miss.

> "The planet is such a stunning sight that it is hard to drag your eyes away from it"

This month's planets

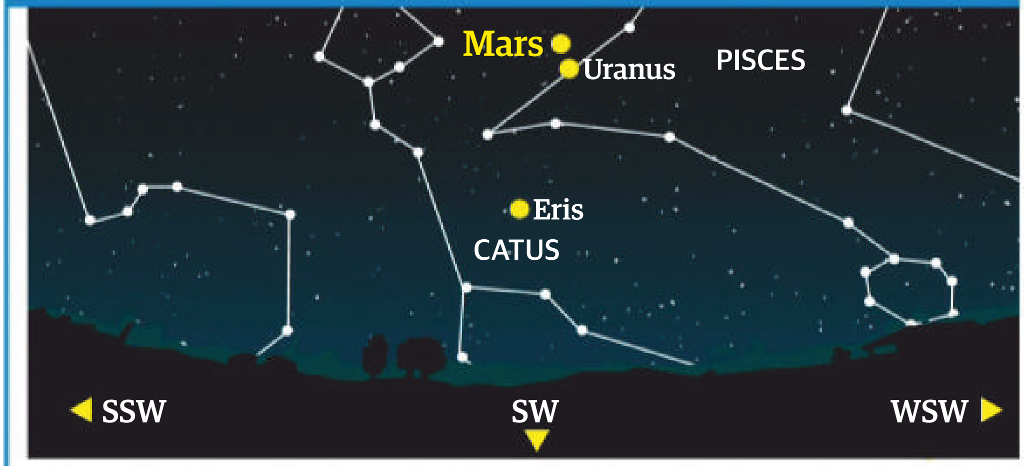
Mercury 18:00 GMT on 19 February



Constellation: Pisces
Magnitude: -0.4
AM/PM: PM

If you want to see Mercury you'll have to wait until the end of the month when it will climb up into the evening sky, becoming visible low in the west-southwest after sunset. On the 19th Mercury will be just one degree north of Neptune, but you'll need a telescope to spot that distant gas planet close to it in the sky.

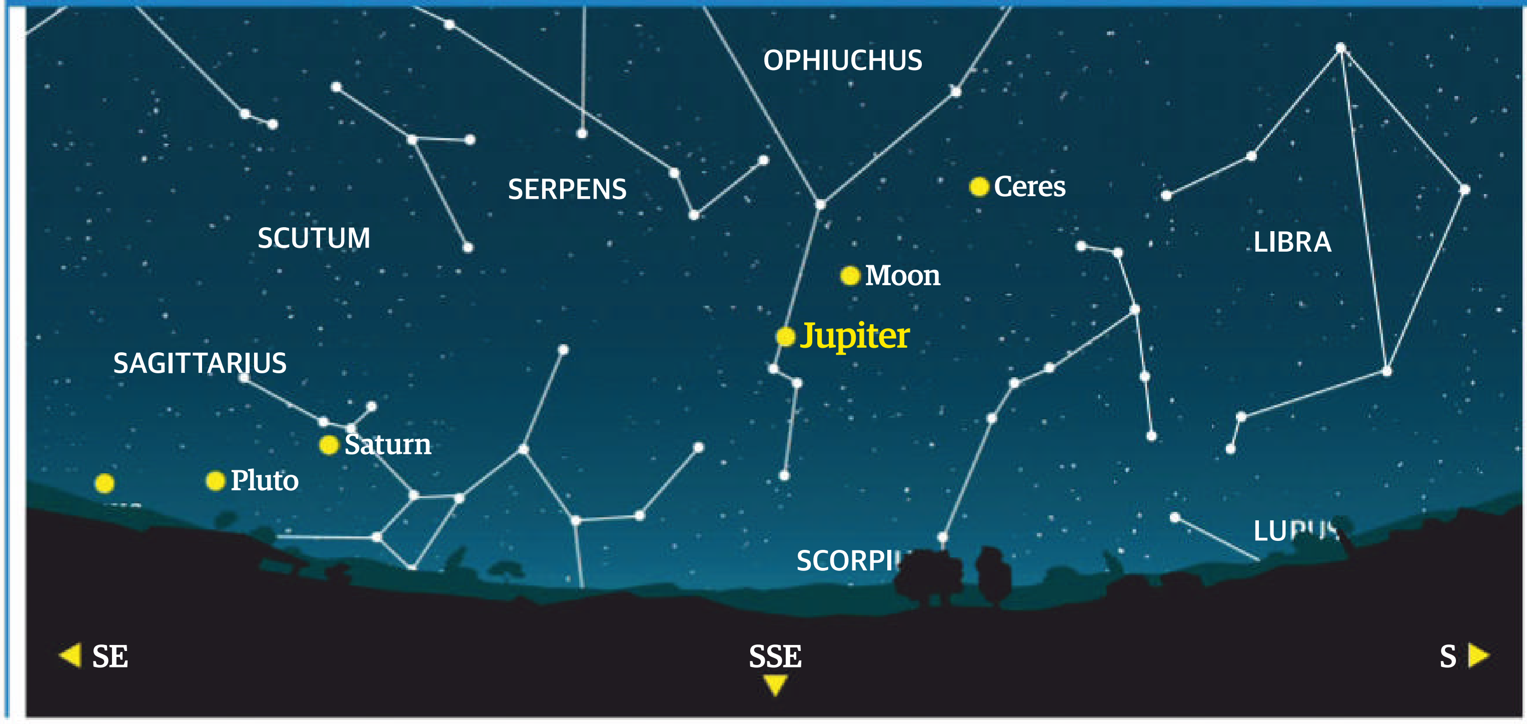
Mars 18:00 GMT on 13 February



Constellation: Pisces into Aries
Magnitude: 0.9
AM/PM: PM

At the start of the month Mars will appear close to the distant gas giant Uranus, and as the month passes the two worlds will move closer and closer together until they are just a degree apart on the evenings of both the 12th and 13th. Look out for a lovely crescent Moon shining close to Mars after sunset on the 10th.

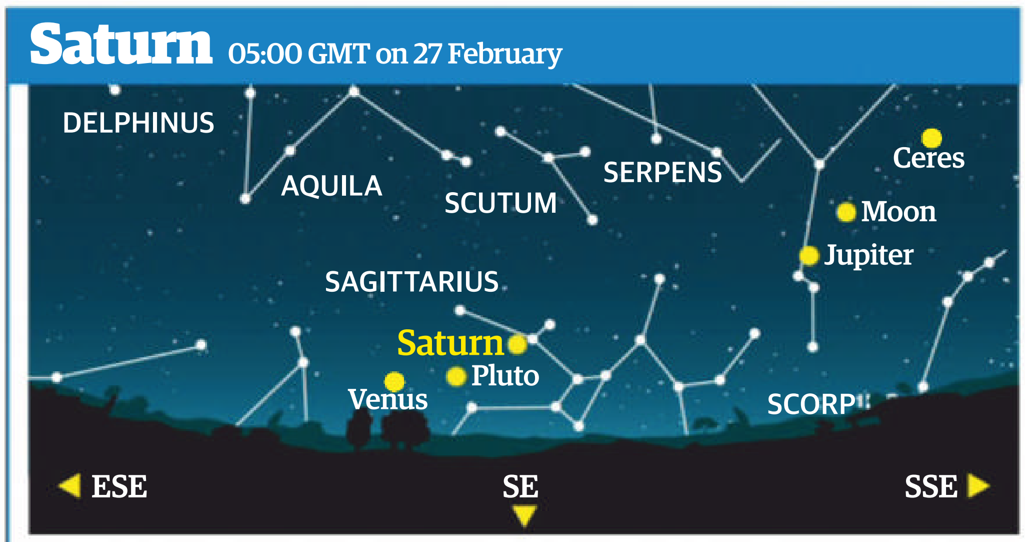
Jupiter 06:00 GMT on 27 February



Constellation: Ophiuchus
Magnitude: -1.9
AM/PM: AM

This is going to be a great month for you if you appreciate the sight of Jupiter, largest by far of all the planets in our Solar System, blazing in the sky. Through February Jupiter is a brilliant 'morning star', looking like a blue-white spark embedded in the stars of Ophiuchus. During this month mighty Jupiter will have lots of company, too. The waning Moon passes it between the 26th and 28th, and you'll also notice Venus shining to the lower left of Jupiter. They start the month just 9 degrees apart, but end it 35 degrees apart, so you'll have the best views at the beginning of the month.

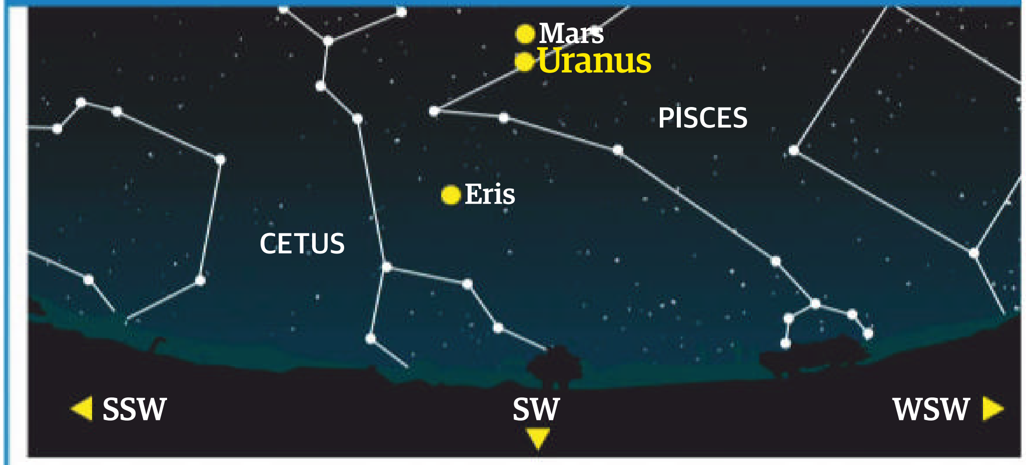
Saturn 05:00 GMT on 27 February



Constellation: Sagittarius
Magnitude: 0.6
AM/PM: AM

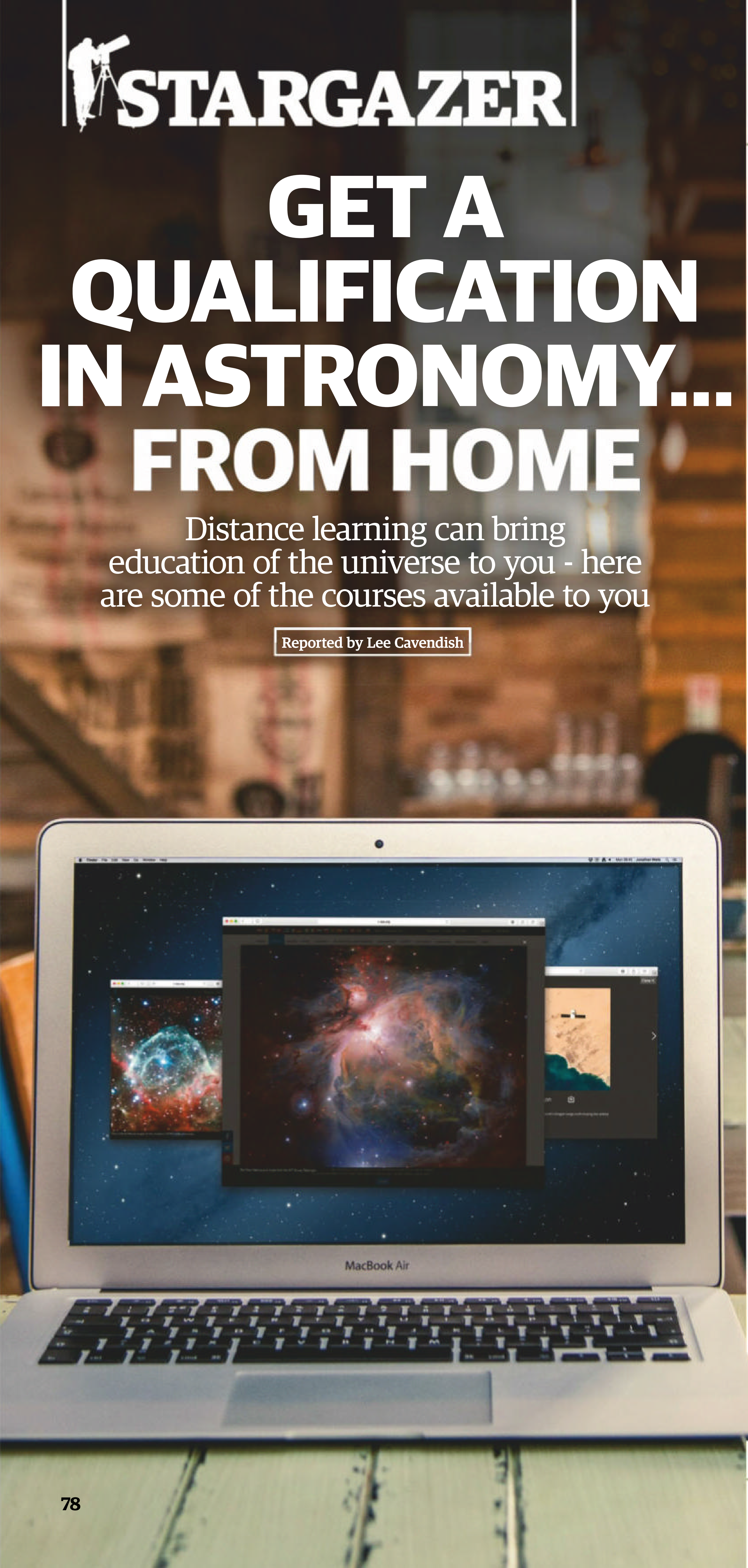
Saturn will be set in the star-rich constellation of Sagittarius, shining just to the upper left of the famous 'Teapot' asterism's handle. You'll need a telescope to see Saturn's lovely rings, but a pair of binoculars will be enough to show you its largest moon, Mercury-sized Titan, looking like a star close to Saturn itself.

Uranus 19:00 GMT on 13 February



Constellation: Pisces into Aries
Magnitude: 5.8
AM/PM: PM

Uranus will be close to much brighter Mars in the evening sky this month, making it easy to find. As the sky darkens find Mars shining in the southwest, and with binoculars look for a slightly green-tinged star close to it. The two worlds will be just a Moon's width apart after sunset on the evenings of 12 and 13 February.



GET A QUALIFICATION IN ASTRONOMY... FROM HOME

Distance learning can bring education of the universe to you - here are some of the courses available to you

Reported by Lee Cavendish

1. Space Studies

Qualification: Bachelor of Science
American Public University,
West Virginia, United States

One option to obtain an astronomy bachelor's degree using distance learning is through the American Public University. The aim of this course is not only to meet institutional and general educational objectives, but also meet the individual objectives of its graduates.

This course is available in a full-time capacity, with it costing £215 ($270) per credit, or £200 ($250) when providing a military grant.

Once graduated, anyone with this degree will be able to demonstrate a firm understanding of basic mathematics, modern aeronautics and spaceflight, a history of space exploration and also the ability to analyse the possibility of life in the universe, while simultaneously studying other astronomical objects such as planets, stars and galaxies.

2. Introduction to Astronomy

Qualification: Online academic course
CourseGate, based in London, England

This is not a full degree, but rather a taster course into the world of astronomy and the cosmos. This course doesn't require any academic background and will thrust you straight into discussions about the universe around us - stars, nebulae, planets, asteroids, moons, galaxies and so much more.

At the time of writing the price of the course has been slashed from £489 ($612) to just £59 ($74)! This course doesn't have any time restraints, so as long as you have a Windows, Mac, Android or any device to load up the course, the universe is at your fingertips!

3. Spacecraft Technology

Qualification: Online academic course
Delft University of Technology, Netherlands

If a short-term online course is more feasible based around a busy schedule, have a look at TU Delft's course in Spacecraft Technology. Exploration of space is an area of science gathering much momentum as access to space is getting easier than ever. This course lasts for a total of 13 weeks, with an estimated effort of 12 to 14 hours of work per week. The price of this experience will be €1,250 (£1,130).

After the 13 weeks this course will have taught the essentials in spacecraft design and manufacture with emphasis on the practical applications. This course does not cover interplanetary rovers or spacecraft instrumentation.

4. Space Studies

Qualification: Master of Science
University of North Dakota, United States

Another option in further education is the unique Space Studies master's degree, available both on campus or online. This is not your usual astronomy course as it offers an extremely interesting and thorough outlook on space engineering, life-support systems, space policy and law, space history and even space-related aspects of business.

This degree is estimated to take between two and four years to complete, and for the online programme the total cost per credit will be £380 ($480). It has been noted that an online student's mandatory fees are capped at 12 credits per semester. If you wish to gain a different outlook on space, studying the lesser-known intricacies of space exploration, it will definitely be worth having a look at this course.

5. Astronomy

Qualification: Bachelor of Science (with Honours)
University of Central Lancashire, England

Barring the Open University, this is the only other place to get a fully fledged astronomy degree from a university in the UK with distance learning. This course prides itself on being able to offer the chance to develop a fascination in astronomy and cosmology while providing the flexibility of self-learning.

For any new students the module fee will be £1,060 ($1,330) whether you are from the UK, European Union or an overseas student. For any student who is continuing on the same award from the previous year, the module fee will be £1,025 ($1,285).

This course has a marvellous range of astronomy topics including modules on the great astronomers in history, an introduction to astrobiology and even the extreme states of matter. This is a rare subject not taught in many of the other distance-learning courses.

6. Observational Astronomy

Qualification: Master of Science
Liverpool John Moores University, Liverpool, England

If you have already obtained at least a 2:2 in a physical science or STEM-based bachelor's degree then Liverpool John Moores University now offers the opportunity to obtain a distance-learning master's qualification to further your education.

If full time is your aim then this degree will take a year to complete, but it will take two years if you decide to do it part time. If you're based in England the cost per credit will be £43 ($54), with international costs still to be confirmed.

This course flaunts some of the world's best academics teaching the wonders of the universe with the help of the robotic Liverpool Telescope. This qualification could open up some optimistic doors for future PhD studies.

7. Astronomy

Qualification: GCSE
Online Astronomy Society Academy, Northampton, England

Calling all astronomy fans in the UK, there is a GCSE course in Astronomy that can be taken thanks to distance learning. This GCSE course will give you the necessary materials online to learn about astronomy, so as long as you have access to the internet you are good to go!

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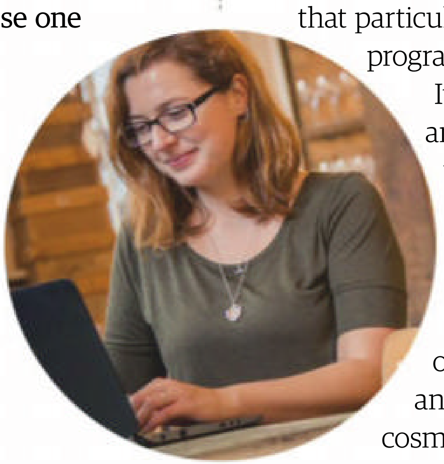
1 American Public University System
2 COURSEGATE
3 TUDelft
4 UND UNIVERSITY OF NORTH DAKOTA
5 uclan
6 LIVERPOOL JOHN MOORES UNIVERSITY
7
8 The Open University
9 DEPARTMENT FOR CONTINUING EDUCATION OXFORD
10

As the length of the course has increased the fees have been increased to £300 (£376), or £150 ($188) per year. This qualification boils down to two exams, one on 'naked-eye astronomy' and the other on 'telescopic astronomy'. These one hour and 45 minute exams, taken in exam centres around the UK, will test your knowledge on the Earth, the celestial systems, the Solar System and much more until you find yourself asking about the big cosmological questions of the universe.



8. Natural Sciences (Astronomy and Planetary Science)

Qualification: Bachelor of Science (with Honours)
Open University, Milton Keynes, England

The Open University, one of the world's best institutes for distance learning, offers a number of degrees - the one we recommend to our readers is an undergraduate degree in Natural Sciences, specialising in Astronomy and Planetary Science.

This undergraduate degree can take three years or six years depending on whether you wish to study full or part time. For anyone based in England the total cost for the qualification would be £17,568 ($22,028), but this will vary for people outside England.

The most exciting aspects of this course include making real-life observations with the Observatorio del Teide in Tenerife, learning a variety of exciting astronomy topics covering the Solar System to the greater universe and developing important mathematical, analytical and investigative skills.

9. Exploring the Universe

Qualification: Online programme
University of Oxford, England

The prestigious University of Oxford offers some intriguing part-time and flexible courses and programmes for adult learners, and one of them that particularly catches the eye is its online programme titled 'Exploring the Universe'.

It is available from just £270 ($338) and will take approximately ten weeks, assuming that 100 study hours have been put into it.

In this programme Oxford astronomers Chris Lintott and Robert Simpson provide an overview of the last 13.7 billion years and educate the student on the entire cosmic evolution - that's a lot to squeeze in! This programme is ideal for providing anyone with a firm grasp on many topics covered in the vast subject of astronomy.

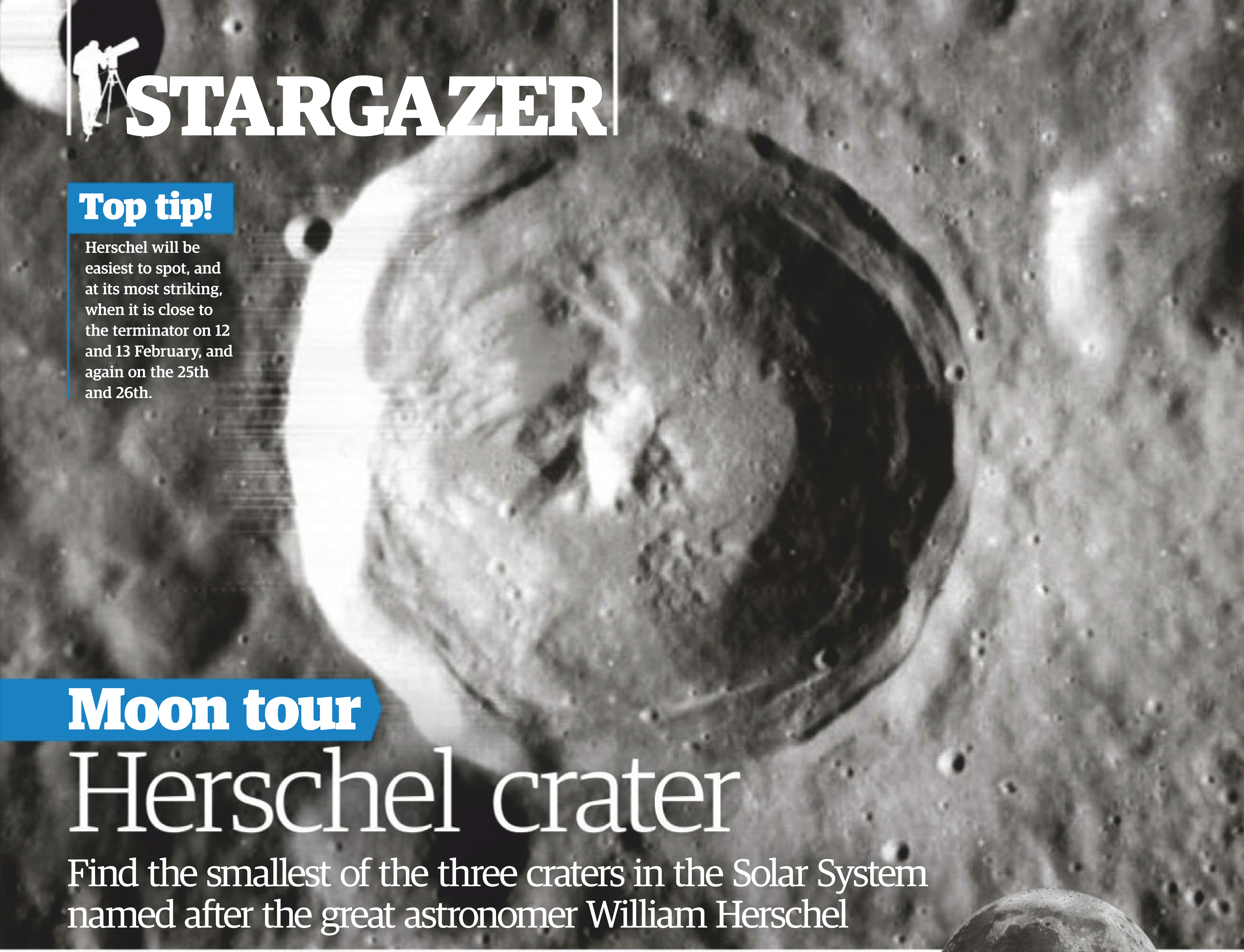
10. Physical Science

Qualification: Bachelor of Science
University of Southern Queensland, Australia

This flexible external course will give you superior knowledge of physics and astronomy, teaching you the fundamental principles of modern science and the laws of physics that shape our universe. For a domestic student the cost would be 21,640 Australian Dollars, or AUD, (£12,440), or a commonwealth support cost of 9,352 AUD (£5,376). For international students the cost will instead be 23,960 AUD (£13,773). This will be over the course of three years, or a part-time course over six years.

For the smart students choosing astronomy will have the unique opportunity to make hands-on and remote-controlled astronomical observations using a series of modern telescopes.

© NASA; ESO



Top tip!

Herschel will be easiest to spot, and at its most striking, when it is close to the terminator on 12 and 13 February, and again on the 25th and 26th.

Moon tour

Herschel crater

Find the smallest of the three craters in the Solar System named after the great astronomer William Herschel

William Herschel was one of history's truly great astronomers. A hugely skilled observer of the night sky, he is best known for discovering the planet Uranus in 1781, but he also discovered that planet's icy moons Oberon and Titania and discovered Saturn's moons Enceladus and Mimas. It's no wonder that his amazing life and important discoveries have been officially recognised by modern astronomers, who have named not one but three craters on bodies after him.

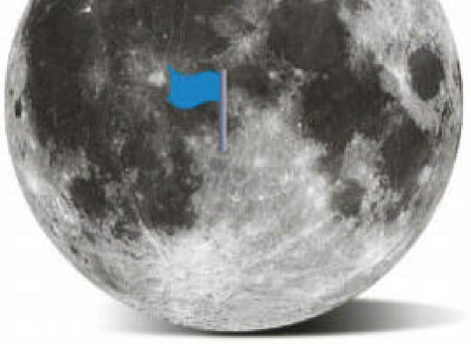
The largest is on Mars - the enormous Herschel impact basin is more than 300-kilometres (186-miles) wide and was named in honour of both William and his son John. The smaller but best known crater named after William dominates Saturn's moon Mimas and gives it its popular nickname of 'the Death Star moon'. Much closer to home Earth's own Moon has a crater named after William too, and that's our destination for this month's Moon Tour.

Of the three craters in our little part of the galaxy named after William Herschel, the one on the Moon is the smallest. Only 39-kilometres (24-miles) across and less than four-kilometres (2.5-miles) deep, it is a classic lunar crater - a roughly circular pit with steep, sharp walls and a mountain peak in the middle. To be honest, if it were anywhere else on the Moon it would hardly warrant a second glance because it would look just like dozens or hundreds of other craters around it. What makes Herschel stand out - and makes it worthy of your attention on the next beautifully moonlit night - is its very close proximity to a trio of much larger craters.

Just below the centre of the Moon, a little to the south of the equator, lies a great chain of three huge craters, all joined together along their rims. At the bottom of the chain, Arzachel is 47-kilometres (29-miles) across. Above it is Alphonsus, more than twice as wide as Arzachel with a diameter of over 110 kilometres (68 miles). At the top of the chain, connected to Alphonsus along its southern rim, is the huge crater Ptolemaeus. 154-kilometres (96-miles) across, Ptolemaeus has a very flat and almost featureless floor, making it look almost like a round tray or plate. Little Herschel, a quarter as wide as Alphonsus, sits a short distance away from Alphonsus' northern rim, and as it is much smaller and deeper it really stands out when you look at it.

Herschel is a young crater in lunar terms, just 400 million years old. Through a telescope at low power it stands out starkly from the rugged southern-highland landscape of the Moon as a roughly circular, sharp-edged pit. Higher magnifications reveal the crater's inner walls are terraced, with ledges and benches of slumped and collapsed rock. In the crater's centre its central mountain peak rises sharply from its floor. The main appeal of viewing Herschel is comparing how deep and detailed it is compared to the much broader, flatter crater to its south.

So when can you see Herschel this month? At the end of January Herschel crater will not be visible because it will be in total darkness. The first chance to see Herschel will come on the evening of 12 February, when the Moon is at first quarter and shining close to the Hyades and Pleiades star



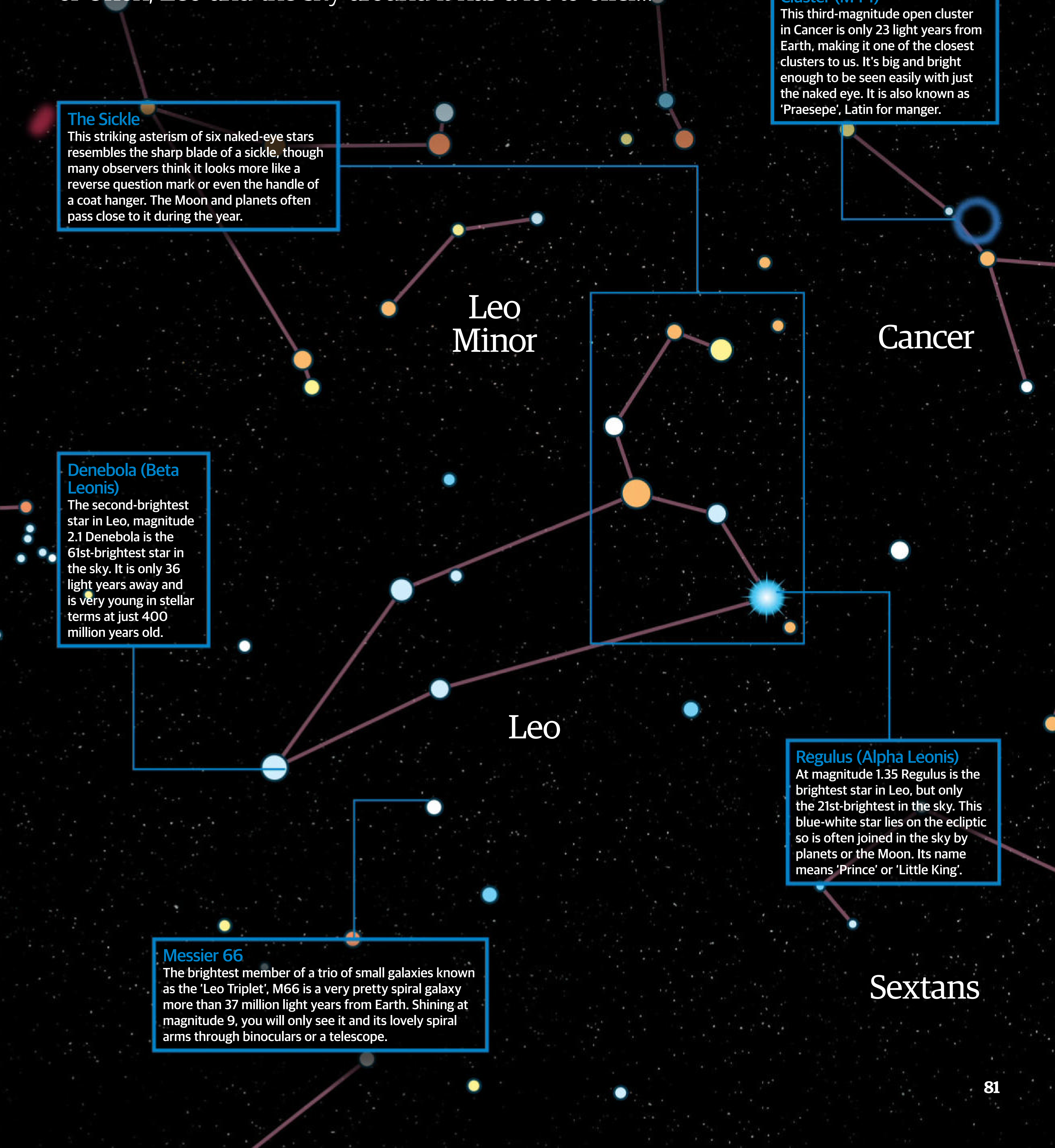
clusters in the evening sky. On that evening the terminator, the line that divides lunar day and night, will have just passed over the crater, so it will be visible as a black hole in the Moon surrounded by a brighter rim. By the following evening Herschel will be in full sunlight, and on Valentine's Day evening it will be obvious even through a pair of binoculars.

As the days pass the Sun will climb higher and higher in Herschel's sky, illuminating more of its floor and inner walls to us here on Earth. By full Moon on the 19th Herschel will have been reduced to a white ring with a grey interior above Ptolemaeus, but soon the terminator will sweep over it again. By the 27 February it will be swallowed up by darkness once more.

© NASA Image Collection / Alamy Stock Photo

This month's naked eye targets

If you can tear your eyes away from the glittering stars of Orion, Leo and the sky around it has a lot to offer...



The Sickle
This striking asterism of six naked-eye stars resembles the sharp blade of a sickle, though many observers think it looks more like a reverse question mark or even the handle of a coat hanger. The Moon and planets often pass close to it during the year.

The Beehive Cluster (M44)
This third-magnitude open cluster in Cancer is only 23 light years from Earth, making it one of the closest clusters to us. It's big and bright enough to be seen easily with just the naked eye. It is also known as 'Praesepe', Latin for manger.

Denebola (Beta Leonis)
The second-brightest star in Leo, magnitude 2.1 Denebola is the 61st-brightest star in the sky. It is only 36 light years away and is very young in stellar terms at just 400 million years old.

Regulus (Alpha Leonis)
At magnitude 1.35 Regulus is the brightest star in Leo, but only the 21st-brightest in the sky. This blue-white star lies on the ecliptic so is often joined in the sky by planets or the Moon. Its name means 'Prince' or 'Little King'.

Messier 66
The brightest member of a trio of small galaxies known as the 'Leo Triplet', M66 is a very pretty spiral galaxy more than 37 million light years from Earth. Shining at magnitude 9, you will only see it and its lovely spiral arms through binoculars or a telescope.

How to...

Use a star tracker

It's possible to take lovely photographs of the night sky with just a camera on a tripod, but with a motorised mount that tracks the stars as they move across the sky you can do much, much more

You'll need:

- ✔ Motorised tracking mount (many different models now available)
- ✔ DSLR camera
- ✔ Sturdy tripod
- ✔ Variety of lenses
- ✔ Cable release
- ✔ Image-processing software

Taking photographs of the night sky and astronomical phenomena has never been easier. Nowadays basic digital SLR cameras take beautiful portraits of the constellations, capture the subtle glow of the Milky Way and catch meteors zipping across the sky. Even the cameras built into our phones can be set to take the time exposures necessary to record conjunctions of the planets, eclipses and even the starry sky itself.

But there is only so much they can do; if you want to capture really faint objects or take very detailed images of the constellations and the Milky Way you need to find a way to take much longer exposures. The problem here is as the Earth turns beneath our feet the stars, planets and other objects in the heavens appear to move across the sky, so unless you can find a way to follow them they will be recorded as trails on long-exposure photos...

Astronomers used to get around this by attaching their cameras to their telescopes as they tracked the sky. Today there are now small motorised mounts that can track the sky independently simply from the top of a tripod, and they can give superb results.

There are lots of different tracking mounts available, but they all work along the same principle: they mechanically turn a camera mounted on them at the same rate as the stars revolve around the Pole Star, thus allowing an astrophotographer to take exposures of up to several minutes in length, more than long enough to capture amazing detail along the glittering trail of the Milky Way, faint comets and nebulae.

Whatever its make, the tracker needs to be mounted on a very sturdy tripod because they are usually fairly heavy pieces of kit. Then a camera needs to be fitted to the tracker via a ball mount, which will allow the camera to be aimed at any point in the sky. The tracker then needs to be manually aligned with the Pole Star, either by sighting on Polaris through a hole in the unit or by lining up on it through the tracker's own small finder telescope. These usually have illuminated sighting circles inside them to assist with alignment, and it's worth downloading a 'Polaris Finder' phone app that supports your particular unit to ensure extra-accurate polar alignment using those circles.

Tips & tricks

Steady as she goes

You'll need a very sturdy, steady tripod to use with a star tracker as they are usually very heavy – much heavier than a DSLR camera.

Keep things tight

Make sure everything on your tracker is fastened tight; if anything is loose, or slipping, your images will show stars as trails, not pinpoints.

Don't over-expose

It's tempting to take exposures several minutes long just because you can, but your tracker will give the best results when limited to under a minute, especially when using heavy zoom lenses.

You have the power

Trackers eat batteries, so make sure you have at least one spare set with you before you head out to take astrophotos.

Taking your exposures

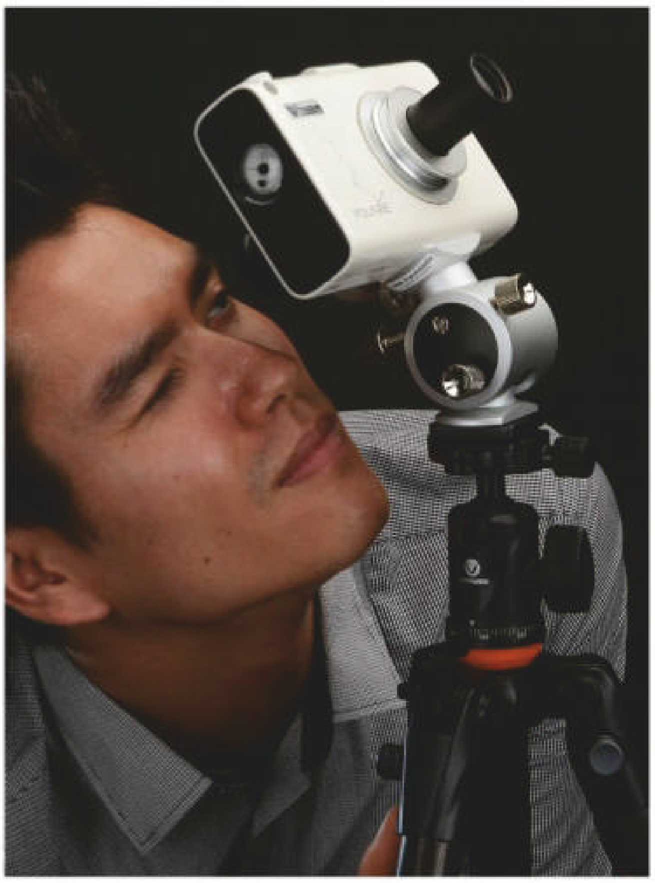
To shoot the perfect image, make sure you're set up well and ready to go

After focusing on a bright star, move the camera to point at your target, and then set it to Manual mode, the ISO to 1600 or so and the exposure length set to your camera's maximum exposure time, typically 30 seconds. If your first test image shows trailed, not pinpoint stars then check your polar alignment and make sure every knob and wheel is tightened up properly.

Send your photos to
space@spaceanswers.com

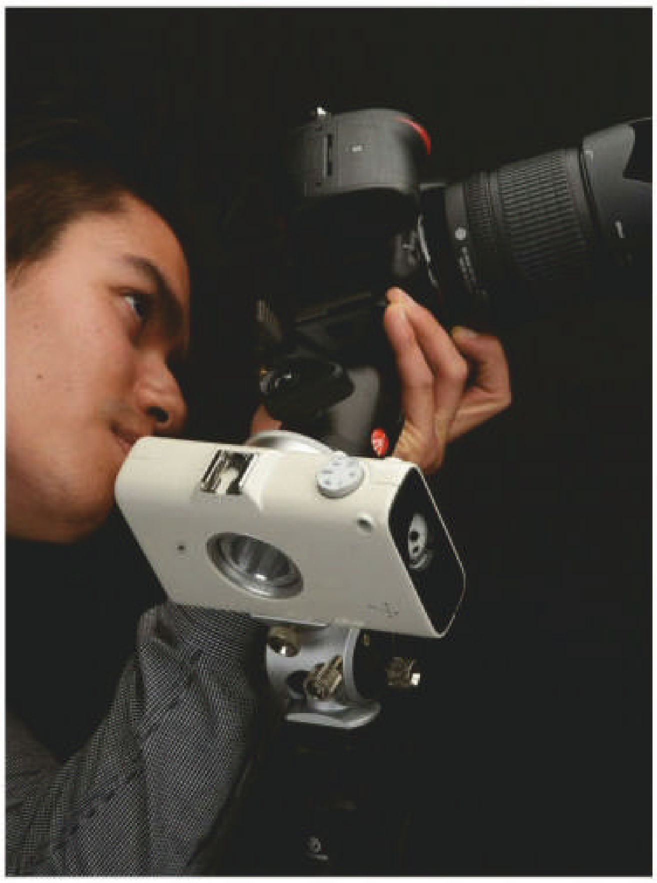
1 Get a sturdy tripod

Mount your tracker on a sturdy tripod and make sure it is level. Next, attach your DSLR to it before aligning it with the Pole Star. A sturdy tripod will improve your images.



2 Align with Polaris

Using the tracker's 'sighting hole' or finder scope, align it with the Pole Star. A phone app will almost certainly be available for your specific model to assist with this.



3 Focus on a bright target

Manually focus your camera on a bright star before moving it to point at your target object or area of the sky. It's easier to focus on a brighter star at first.

4 Start your test exposures

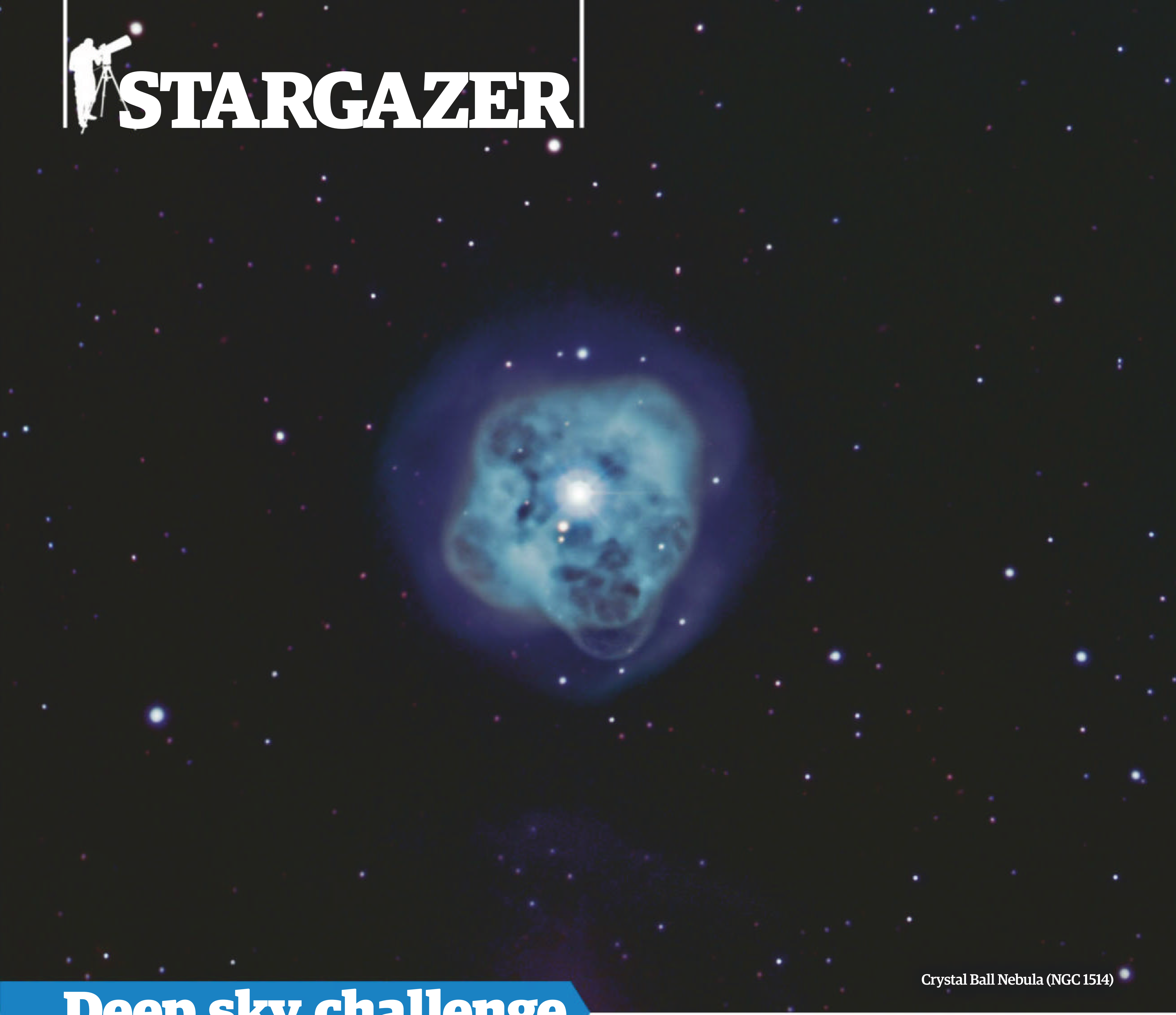
Take a test exposure of 30 seconds with the ISO set to 1600. If the stars have trailed, check your polar alignment and tighten everything up.

5 Ensure everything is operating as it should

Keep your exposures to under two minutes to reduce potential trailing. Check regularly that your lens hasn't misted up and check it's still in focus.

6 Use stacking to get a high-resolution image

Use free software to process your images. You can stack lots of images of the same object together to make a single high-resolution image.



Crystal Ball Nebula (NGC 1514)

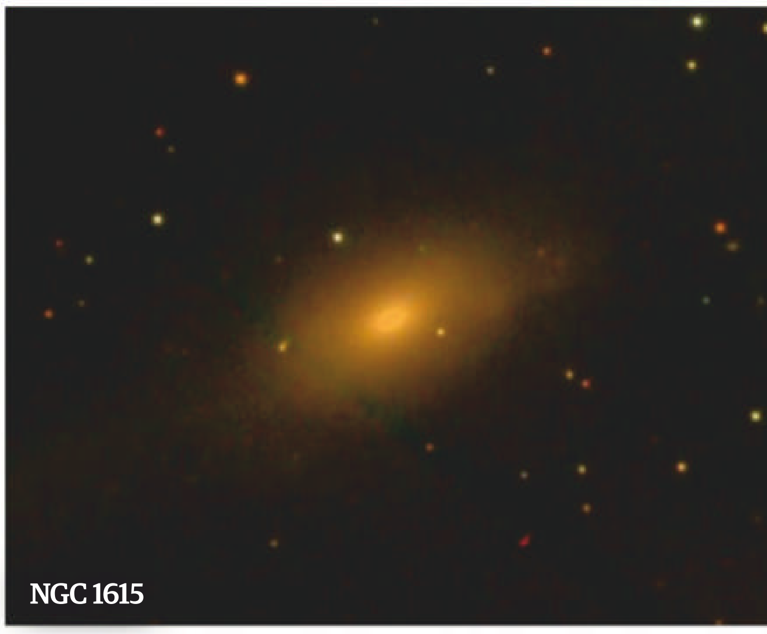
Deep sky challenge

Tantalising treats in Taurus

There's more to the Bull than the Pleiades and the Hyades clusters - if you're up to the challenge

Many constellations are famous for one or two well-known and beloved deep-sky objects. Orion is famous for the Orion Nebula and the neighbouring Horsehead Nebula; Lyra's 'celebrity feature' is the Ring Nebula, M57, and pretty much the only reason for pointing a telescope or pair of binoculars towards the little box of Cancer is to look at M44, the Beehive Cluster. Likewise, when you think of Taurus you automatically think of its two large, bright open star clusters, the V-shaped Hyades cluster and the 'Mini-Big Dipper' of the Pleiades cluster, M45. However, there are other deep-sky objects lurking within the borders of this zodiacal constellation well worth your time tracking down.

You might not think of M1, the famous 'Crab Nebula', as being particularly challenging, but it is if you live anywhere with skies that are corrupted by even low levels of light pollution. Our other objects - remote galaxies, clusters and nebulae - will all require medium- or large-aperture telescopes to see, but all offer something refreshingly different from the beautiful, but very familiar jewelled sprays of the Hyades and Seven Sisters. So, telescopes at the ready, swing them towards Taurus and let's go...



NGC 1615

1 Struve's Lost Nebula (NGC 1554)

In 1868 deep-sky observer Otto Struve observed a nebulous region close to the star T Tauri – but he never saw it again, and no one else ever has. Can *you* see anything 4' WSW of the star?

2 IC 353

Just to the north of the Pleiades lies a short, faint swath of nebulosity. Tenth-magnitude IC 353 is a gaseous nebula 460 light years away and 24 light years wide. You'll need a small- to medium-aperture telescope to see it.

3 NGC 1807

This seventh-magnitude open cluster is little more than a loose spray of 20 or so faint stars close to Taurus' southern border with Orion. High magnification will isolate its members.

4 NGC 1615

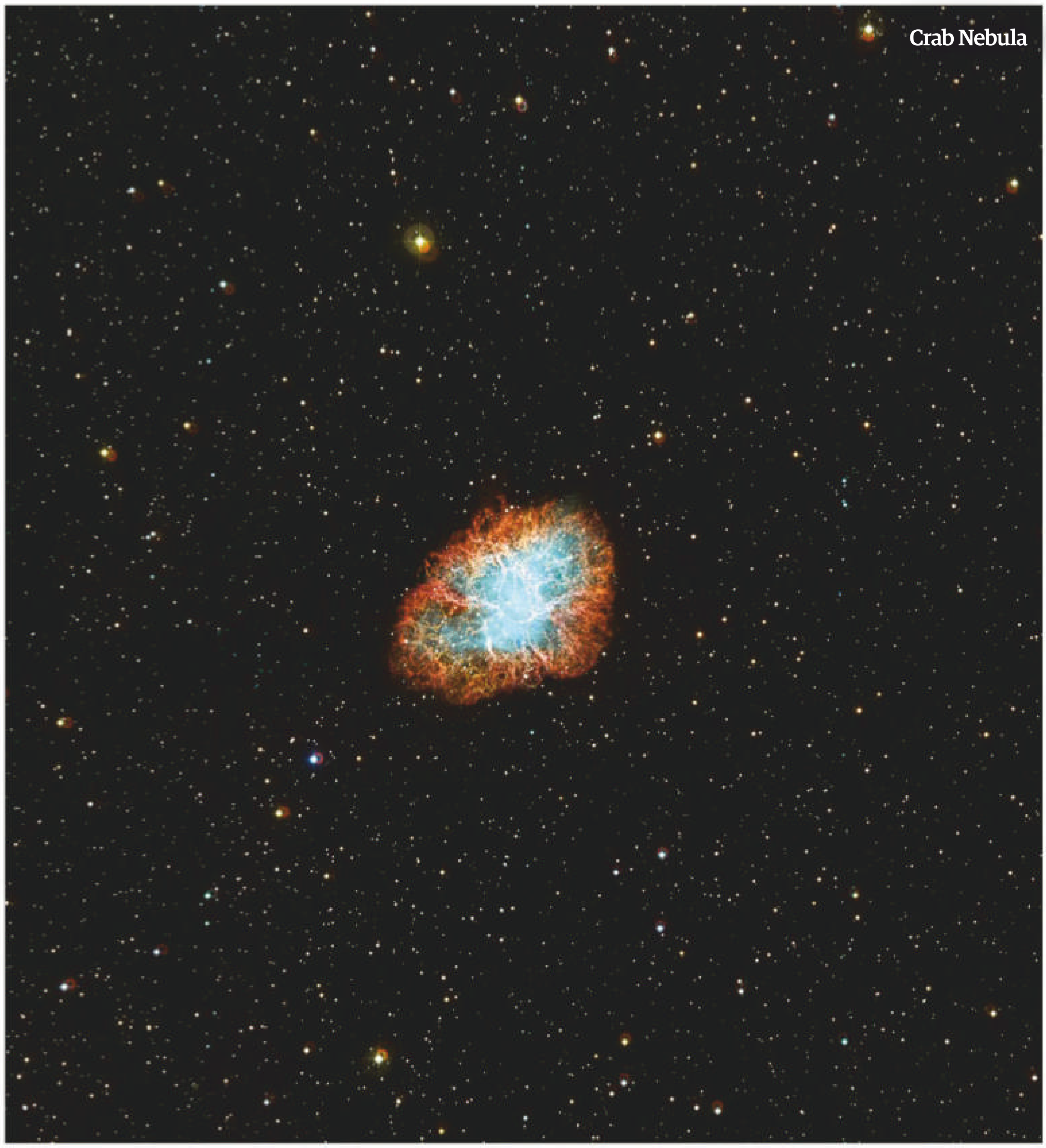
Close to the Horns of the Hyades, this 12th-magnitude elliptical galaxy will only be seen through large telescopes under dark skies, appearing as a small, slim oval smudge.

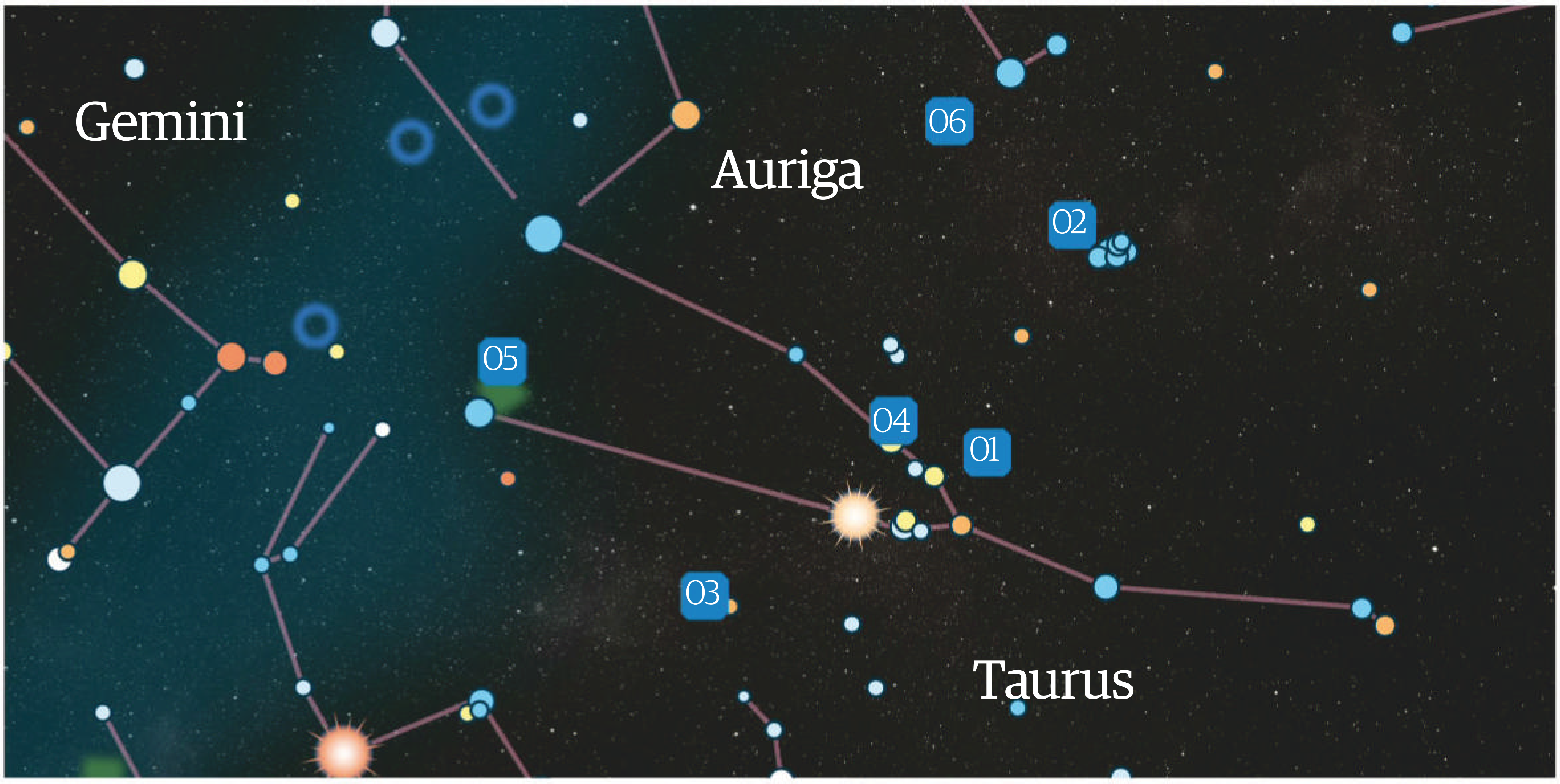
5 The Crab Nebula (Messier 1)

At magnitude 8.4 the famous supernova remnant M1 might sound like an easy object to find, but its small size and low surface brightness mean any light pollution or moonlight will drown it out. You'll require a medium telescope at least.

6 Crystal Ball Nebula (NGC 1514)

You'll need a medium- or large-aperture telescope to see this magnitude 10.9 planetary nebula. With a faint outer edge and bright interior blobs and clumps some think it resembles a tiny open flower.





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How to...

Choose the right astronomy app

Amateur astronomy has been revolutionised by the use of apps on smartphones and tablets. How do you pick the right ones for you?

You'll need:

- ✔ Smartphone or tablet device
- ✔ GPS enabled on your device
- ✔ Access to the internet via WiFi
- ✔ Sufficient memory on your device to download large apps

Before the advent of apps, amateur astronomers used to rely on books and monthly magazines for our astronomy news, information about space missions and details of what would be visible in the night sky. Then home computers entered our lives, and suddenly we were able to use amazing planetarium programs to simulate the night sky and help us plan observing evenings in advance. They were very crude and simple compared to what we have today, but they genuinely revolutionised the hobby.

A second revolution followed when the internet exploded in popularity. Now we were drowning in information about space missions; able to access the actual images taken by space probes and landers exploring distant planets, comets and asteroids and even talk to the people involved in the missions. Soon online communities of amateur astronomers had formed, places where people could give advice, share photographs and learn from others with the same passion.

In recent years there has been a third, even more dramatic revolution in amateur astronomy as smartphones and tablets have taken over our everyday lives. There are now hundreds, and perhaps even thousands of astronomy apps available – far too many, to be honest. Some apps turn your mobile device into a 'pocket planetarium', generating detailed sky charts for where you live. Others predict when you will be able to see the International Space Station crossing the sky, or a display of the northern lights or eclipses of the Sun and Moon.

With so many apps available it's important to decide exactly what you want apps for before downloading any. Some basic apps are free, and still very useful, while others cost a fortune and are bloated and hard to use because they try to do absolutely everything, gorging themselves on your device's memory and power as they chug away. Do your research in advance and only download apps you will actually use.

> "Some basic apps are free, and still very useful"

Tips & tricks

Decide what you need

Take time to figure out just what you need apps for – only download those that suit your needs.

Read the reviews

Some might highlight compatibility issues with your device or bugs.

Check for permission requirements

Be very careful to check what an app will want to do with your information and access to your device. Many want to access your contacts, emails and texts for no good reason. Avoid those.

You get what you pay for

Although some basic, free astronomy apps are very good, it is often worth paying for the more advanced apps.

Be patient with your apps

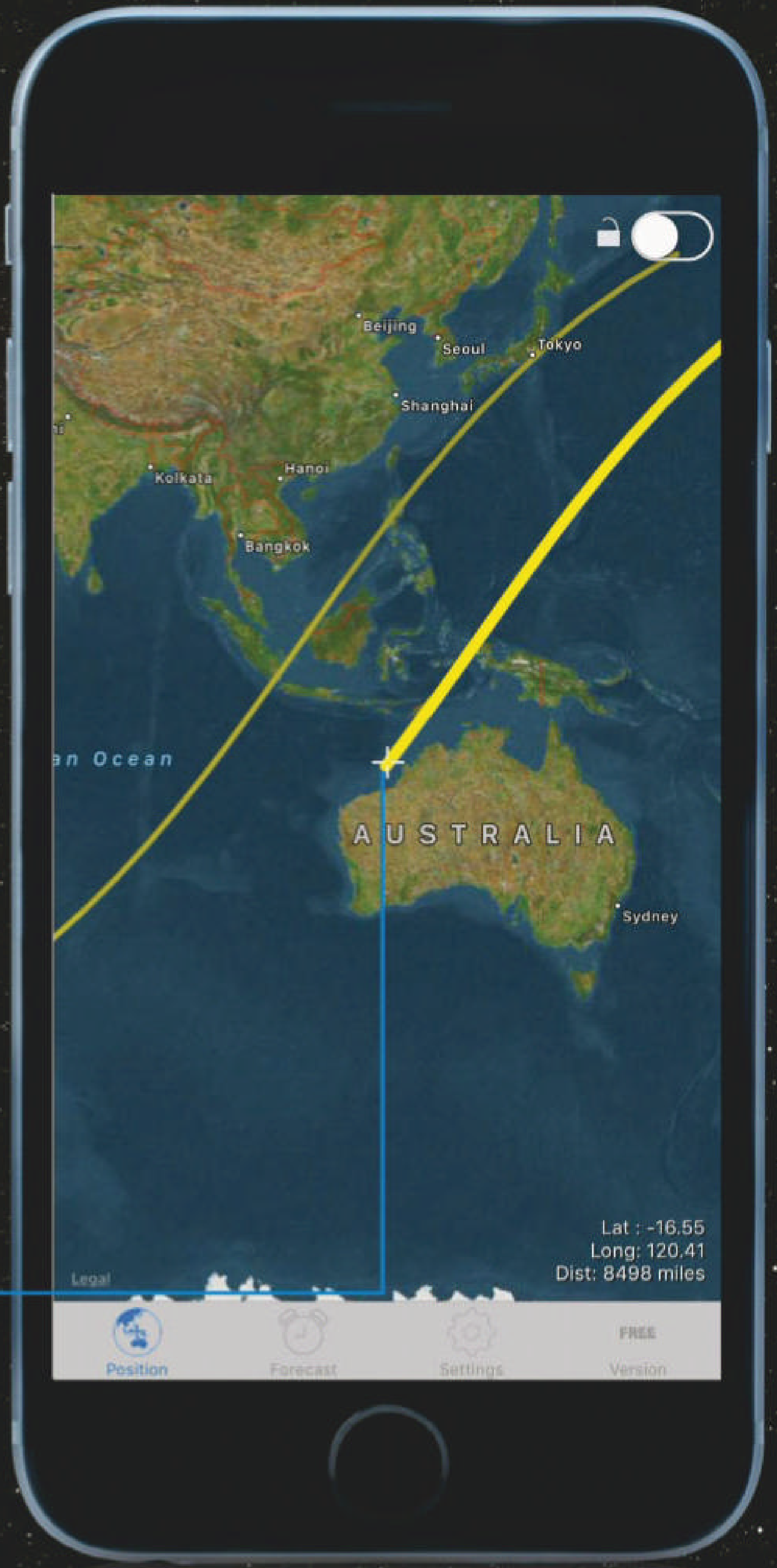
More advanced apps have so many features, they take a little while to figure out everything they can do.

Quick tips for choosing an app

With so many available, here's how to select the one for your needs

Some people have a particular area of interest that they focus on in astronomy, such as planetary or deep-sky observation. If yours is quite niche there might be an app dedicated to exactly that, such as aurorae forecasts or a Moon map, whereas an app that does everything might be hard to navigate and take up lots of extra space. You can also rely on other users' reviews and star ratings in the app store.

Send your photos to
space@spaceanswers.com



☑ Your own needs

Before downloading any apps consider what you specifically want to use them for. You might not need to download large apps if smaller, specialised ones will be more useful.

☑ Read reviews

Make sure you read the users' reviews before downloading an app. You might learn it is incompatible with your device or has other issues.

☑ Look up!

Other apps will give you early warnings of when you can see the Space Station and other satellites crossing the sky. They tell you when and where to look.

☑ Browse the app store

Go to the site you download apps from and search carefully for astronomy apps that will actually be useful and help you enjoy stargazing.

☑ Pocket of stars

A planetarium-type app will help you learn the sky. As you move your device the app will label the stars and constellations visible above you.

☑ A better view

You can even use an app to watch live video of the Earth being beamed down from the Space Station as you sit on the bus or relax at home!

All About Space recommends

Sky Safari is a versatile planetarium app which will help you learn the night sky. V5 is free, but the most advanced version is £18.49.

The free Stellarium app is not as advanced, but simulates the night sky beautifully and realistically. It's good for basic observation planning.

The free Heavens Above is great for predicting when and where you can see the Space Station and other satellites crossing the sky. Also has a premium version.

The Clear Outside weather app is very accurate and reliable, with useful information about cloud cover and seeing conditions that might ruin your night.

The Northern Hemisphere

There's still a chill in the air as February rolls around, offering those clear, crisp sights

The 'Dog Star' Sirius starts to dip low towards the horizon, below and to the left of Orion (the Hunter). Meanwhile, Taurus (the Bull) can be spotted on the other side of the famous Belt of Orion while Gemini (the Twins) is high in the south. You'll be able to locate the twins with ease thanks to its member stars Castor and Pollux. Gemini also hosts some beautiful deep-sky targets, including the Medusa Nebula (Abell 21), the Eskimo Nebula (NGC 2392) and open cluster Messier 35.

Coming to the end of winter, you'll still be able to locate the Hyades cluster in Taurus, which sits close to bull's eye Aldebaran, with the naked eye, as well as the Pleiades, also known as Messier 45.

Using the sky chart

This chart is for use at 10pm (GMT) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

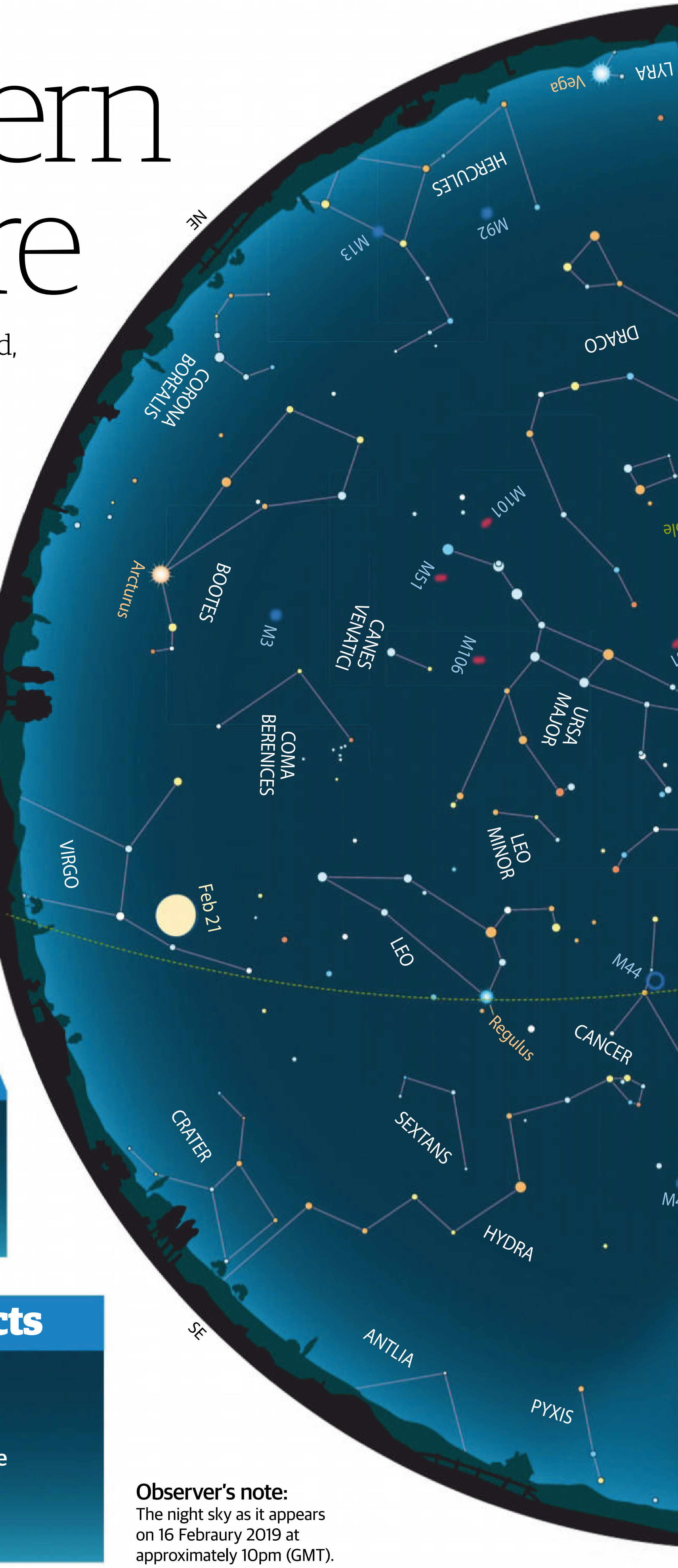
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- ● 1.5 to 2.0
- ● 2.0 to 2.5
- ● 2.5 to 3.0
- ● 3.0 to 3.5
- ● 3.5 to 4.0
- ● 4.0 to 4.5
- ● Fainter
- ● Variable star

Spectral types

- ● O-B
- ● A
- ● F
- ● G
- ● K
- ● M

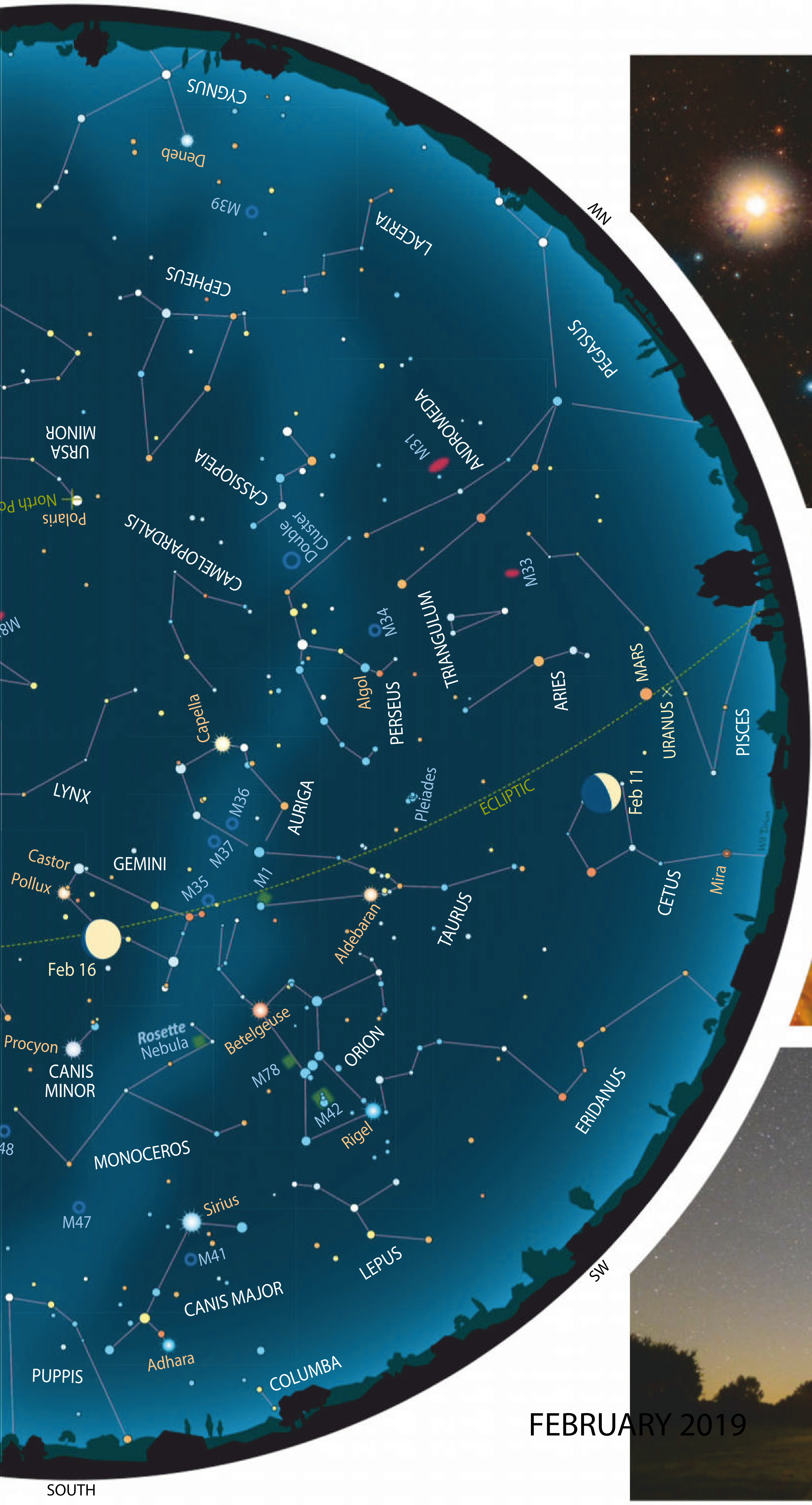
Deep-sky objects

- ○ Open star clusters
- ● Globular star clusters
- ■ Bright diffuse nebulae
- ○ Planetary nebulae
- ● Galaxies



Observer's note:
The night sky as it appears on 16 February 2019 at approximately 10pm (GMT).

The Northern Hemisphere



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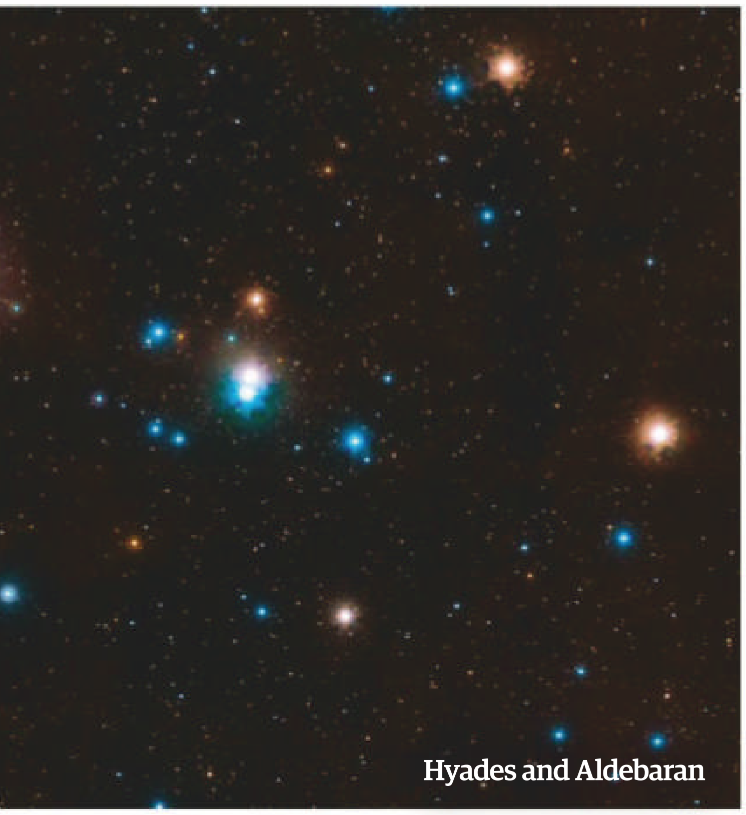
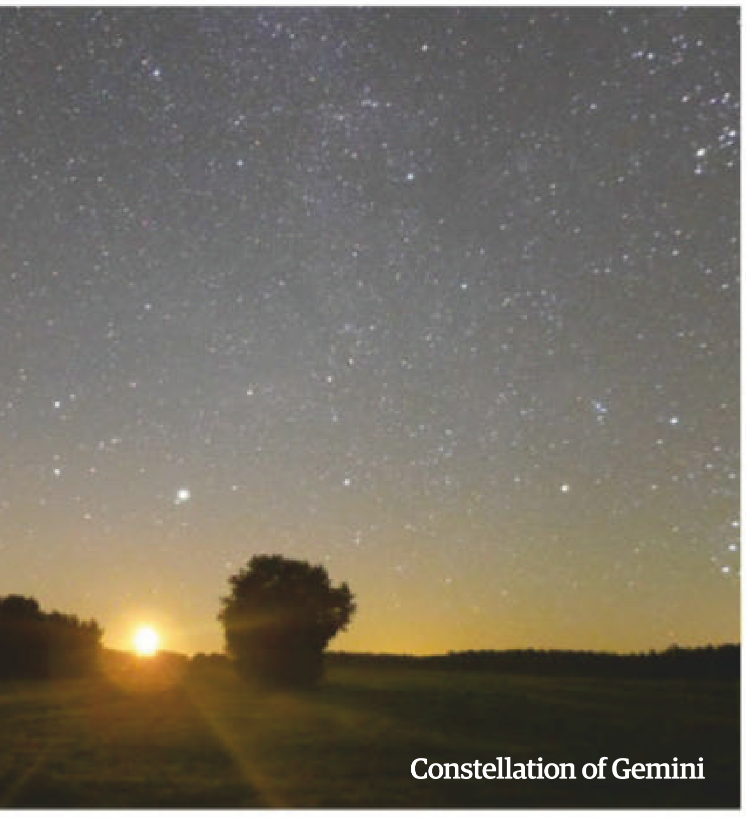

Hyades and Aldebaran

Medusa Nebula


Constellation of Gemini

© Wil Tirion; ESO; Giuseppe Donatiello; Alejandro Sanchez de Miguel

Astroshots *of the month*

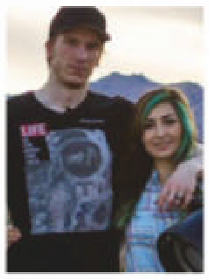
Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Stacey Downtown

Birmingham, UK

Telescope: Sky-Watcher ED80

"A two-panel mosaic of the North American Nebula (NGC 7000), which also shows a good proportion of the Cygnus Wall - a cosmic ridge that spans for about 20 light years. Using an Altair Astro Hypercam 183C, I'm extremely pleased with the result since I image from a light-polluted location."

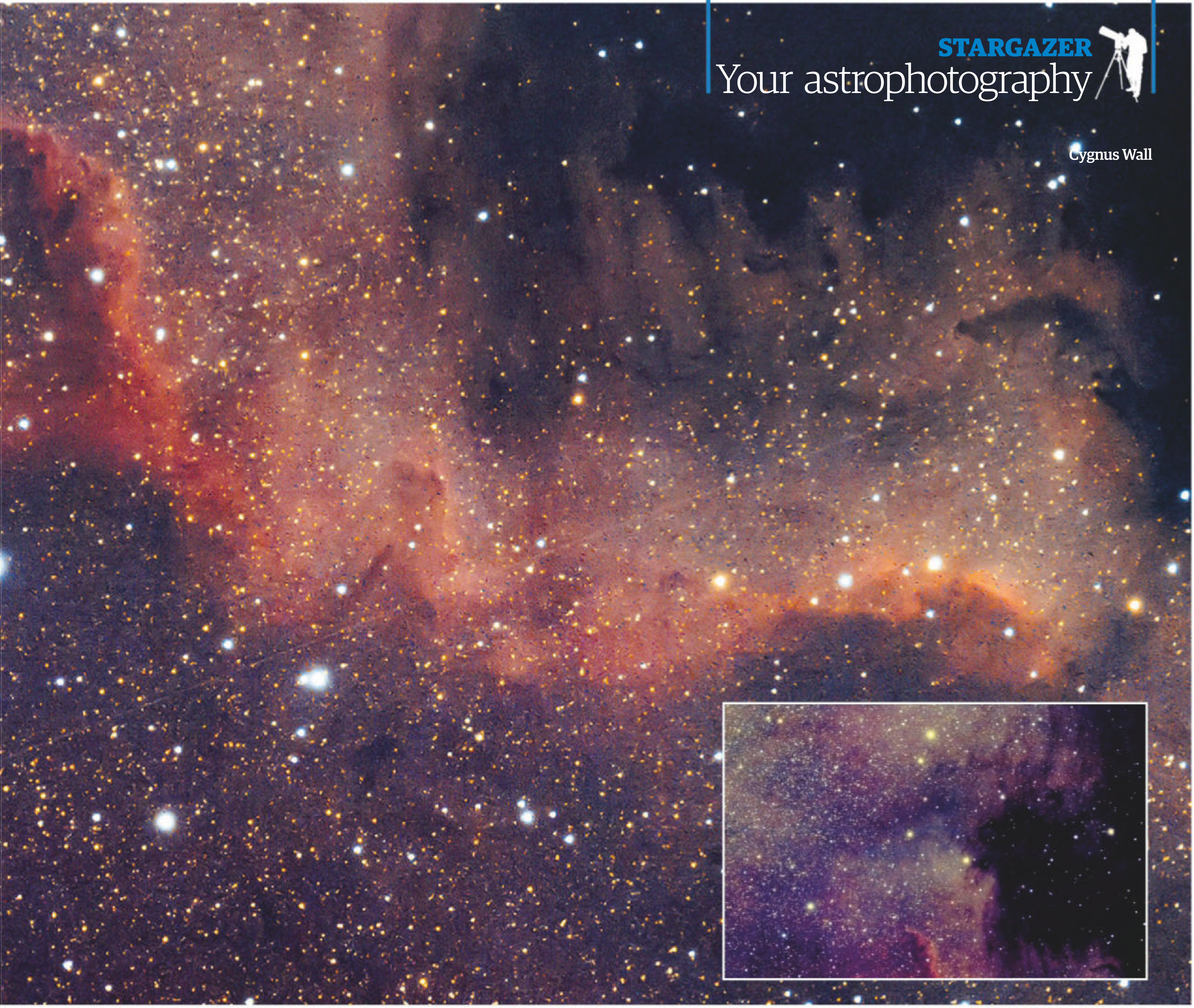


Antoine & Dalia Grelin

Nevada, United States

Dalia and I have been enjoying the dark skies of the Nevada desert for years. When we took our first night trip into territories untouched by light pollution, we were completely astonished by how many stars were visible just one hour away from the city. Las Vegas might be one of most light-polluted cities in America, but it's surrounded by the desert! That evening we took a couple of photos with our point-and-shoot camera, which were not great, but we could see the Pleiades, known as Messier 45, in one of them. Ever since, we've been photographing the night sky for years."

Orion Nebula (M42)



Cygnus Wall

Jamie Cooper

Northamptonshire, UK

"I captured the Christmas comet, Comet 46P/Wirtanen, making a close approach to the Earth on 15 December. In the night sky it could be found close to the Pleiades, an open cluster also known as Messier 45. I've also been interested in photography for as long as I can remember, so it was only a matter of time before I started to combine it with astronomy, and a life-long passion for astrophotography was born. Over the years I have travelled the world searching for some of the most wonderful sights in nature to observe and photograph such as solar eclipses, comets and displays of the Northern Lights."

Comet 46P/Wirtanen & Pleiades (M45)

Send your photos to... @spaceanswers @ space@spaceanswers.com

Meade Polaris 114 EQ

Sturdy and easy to set up, this reflector also allows for pleasing observations of a wide variety of targets

Above: The Polaris 114 EQ employs a German equatorial mount

Telescope advice

Cost: £250 (approx. $320)
From: Currys
Type: Reflector
Aperture: 114mm
Focal length: 1,000mm

Best for...

- ? Intermediate
- £ Small budget
- Solar System targets
- Lunar surface
- Bright deep-sky
- Basic astrophotography

As ever, Meade has provided a telescope that boasts a superior build over other instruments within its price range. Finished off to a high standard, the manufacturer of the Polaris 114 EQ has provided a very good selection of eyepieces as well as a 2x Barlow lens for low, medium and high magnification that not only saves a dent in the bank balance, saving the observer from having to buy countless accessories, but also ensures that the amateur astronomer has everything they need for an evening under the night sky. Similar to the telescope itself, the accessories are well-made with no signs of finishing glue or stickiness that we've encountered with other telescopes below the £300 price range. There were a couple of negative points, however: the red-dot finder's construction isn't the best, being made of plastic, but it certainly got the job done. Also, the AutoStar instructional DVD that comes with the telescope is unfortunately unable to be used on a Macintosh computer.

Assembly is quick and easy. While Meade Instruments always provides a comprehensive manual with each of its telescopes, we found the setting up very intuitive to the point that we rarely needed to refer to it, making the 114 EQ ideal for those wanting a telescope that's quick and easy to set up, doesn't want their observing time cut into or those who are in the early stages of learning their way around the night sky. If you're used to using a 'scope that employs an alt-azimuth mount then you may find the setting up and use of the Polaris 114 EQ's German equatorial quite tricky. However, full guidance is provided in the supplied manual, which is packed with very useful information. If you're unsure of how to get the best out of an equatorial mount then we advise doing a bit of research on them before you get stuck into your observations. Polar aligning is an easy task once the observer knows how to use this type of mount.

We had an excellent run of clear skies throughout January and, combined with a dark-sky site, the night sky was our oyster. Being a reflector the Polaris 114 EQ allows you to choose between a selection of deep-sky and Solar System targets – small-aperture refractors seem to fare better with bright targets, such as the planets and the Moon.

Observing just before dawn gave us the opportunity to make the most of gas giant Jupiter, shining at a dazzling magnitude of -1.82. Views of the planet were clear and crisp thanks to the refractor's optics, which have been smothered with anti-reflection coating. Through the field of view we were treated to a pale disc, with the Galilean moons strung out either side of the gas giant's limbs as points of light. Peripheral vision afforded us the opportunity to spot the planet's equatorial bands.

We were keen to enhance our viewing experience so included a selection of coloured filters – orange,

Right: The red-dot finder is flimsy but does the job when navigating the night sky

Left: The reflector's optical system allows observations of deep-sky and Solar System targets

light red, dark red, dark blue and violet – fitting these to the supplied eyepieces which provide an easy-screw barrel to make threading attachments a breeze. Using a high-power eyepiece pushed the reflector's limiting magnification too far, producing blurry images of the king of the Solar System, so we recommend using 'low-power' eyepieces when viewing closer planetary targets.

Moving to the southwest in the evening we made contact with Mars, which shone at magnitude 0.63. As expected, views of the planet were crisp and clear, the Red Planet appearing as a salmon-pink disc. Meanwhile, a waning crescent Moon with 15 per cent illumination allowed us to obtain views of the rugged lunar surface, with pin-sharp sights of craters and lunar mare of exquisite contrast.

If you want to try your hand at some very basic astrophotography then the equatorial mount allows for sturdy photography using either a smartphone or DSLR camera. Tracking is also easy with the Polaris 114 EQ using the setting circles for Right Ascension and Declination and the slow-motion controls for a pleasantly smooth experience. If you aren't keen on continually turning the knobs to track planets and other targets during lengthy observations then we recommend purchasing a motor for the mount.

Deep-sky objects such as bright star clusters could be observed with ease using the telescope's good optical system. The Great Globular Cluster in Hercules, also known as Messier 13, appeared as a small, fuzzy ball through the field of view, while a selection of double stars could be split very easily. The Polaris 114 EQ is able to provide views of objects beyond our Solar System as well as inside it, making it suitable as a more advanced beginner scope or for those who are keen observers of a variety of targets and don't want to be restricted to one kind of astronomical target.

Below; A 2x Barlow lens and two eyepieces are supplied

> “We found the setting up very intuitive to the point that we rarely needed to refer to the manua ”

WIN A MEADE POLARIS 114 REFLECTOR

Perfect for both beginners and more advanced users, this telescope presents some of the sky's finest Solar System and deep-sky targets

Reveal the wonders of the cosmos with the slew of a telescope tube. The Meade 114-millimetre (4.5-inch) equatorial reflector telescope is a great place to start if you're new to observational astronomy or need a 'grab and go' instrument for those quick views of the night sky. You don't just get a telescope in the package – it also comes with three eyepieces, two Barlow lenses and an accessory tray as well as an Autostar Suite Astronomy DVD.

The Meade Polaris 114 provides easy access to a wide array of celestial objects, whether it's Sirius twinkling in Canis Major, the fabulous Cat's Eye Nebula or even our neighbouring spiral, the Andromeda Galaxy. The refractor's lightweight design and ease of assembly means that you spend more time gazing upon the wonders of the night sky than setting up.

To be in with a chance of winning, all you have to do is answer this question:

Which was the first spacecraft to orbit the Moon?

A: Apollo 8

B: Lunar Orbiter 1

C: Luna 10

Competition ends on 28 February 2019

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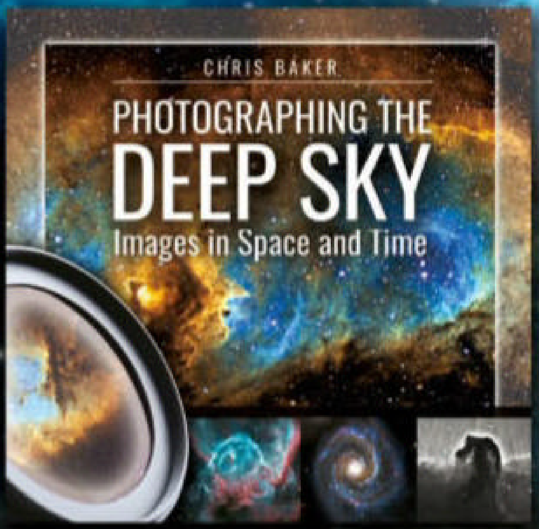

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Space and time and the evolution of the Earth are interwoven using beautiful images of the Deep Sky in this accessible and richly illustrated book.

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1. Guide **Collins Planisphere**

Cost: £9.99/$15.30 **From:** Harper Collins

Perhaps one of the most essential pieces of kit for anyone requiring aid for navigating the night sky, a planisphere is a necessity.

Our first test was to see if the planisphere is still readable under red light, which is used by astronomers to preserve night vision. Taking the planisphere outside, every detail on the map is visible, ensuring that – whatever constellation in the Northern Hemisphere you're looking for – you can still use it with ease. Many budding astronomers can be overwhelmed when first getting to grips with using a planisphere, but with practical instructions printed on the back, we found it easy to follow; it simply directed us to dial in the date and time at our location by rotating the discs.

Overall we are impressed with the detail on this planisphere, along with the high-quality material it is made from – an all-over laminate ensures that condensation can simply be wiped off without damaging the plastic and, of course, also ensures that the planisphere can be used for many observing sessions to come.

2. App **GoSkyWatch Planetarium v. 9.1**

Cost: £2.99/$3.99 **From:** iTunes

It's possible to get stargazing apps for free on your smartphone, but GoSkyWatch Planetarium is an app worth shelling out for.

When fired up the sky was immediately correctly orientated, no matter how our phone was tilted, and we weren't restricted to a portrait or landscape view of the night sky. The app's graphics are pleasing to the eye and packed with detail. Some may be put off by GoSkyWatch only showing naked-eye stars, but we think that the 'sky view' looks a lot less cluttered and confusing for those finding their way around the night sky.

Pinching the night sky allows you to see an entire dome of stars, as well as those below the horizon, while stretching enabled us to zoom in to sections of interest. The icons – which offer a variety of functions, including the option to post your observations on social media, what the sky looked like in the past and might in the future, as well as a red backlight to preserve your night vision – are excellent additions to an astronomical app.

3. Book **Einstein's Monsters**

Cost: £18.99 **From:** W.W. Norton & Company Ltd

Einstein's Monsters: The Life and Times of Black Holes by astronomer Chris Impey chronicles the astonishing science behind one of the universe's most exotic objects, tying in their role in our quest to understand the history and future of the cosmos.

Given the difficulty even professional astronomers have in wrapping their minds around black hole astrophysics, Impey does an impressive job of relaying a complex subject to a wide audience. In fact, he does it in such a way that the imagination is truly captured, without resorting to 'dumbing down' the physics that make the black hole a truly mind-bending and wondrous member of the universe.

If you hold a qualification in astrophysics or are up to date on the research into black holes you'll be familiar with a lot of the book's content – if you don't, you won't regret picking it up.

4

4. Motor drive **Meade Polaris DC**

Cost: £44.99 / $39.95 **From:** meade.com or meadeuk.com

You can usually find this accessory inside the box of Meade Instrument's Polaris EQ model of telescopes. However, if you're looking for that extra assistance in tracking a variety of targets in the night sky and own the 70 EQ or any of the Polaris range up to 130 EQ, then the Polaris DC motor drive attaches easily to your instrument.

Align your Polaris EQ telescope to the pole and the 9V battery that powers the drive will keep your chosen object in the field of view for 10 to 20 minutes before it will need to be recentred. Suitable for both the Northern and Southern Hemisphere, the Meade Polaris DC allows you to devote your undivided attention to the wonders of the universe instead of painstakingly and manually tracking them. Leave it permanently installed and set-up times are conveniently eliminated.

3

HEROES OF SPACE

Fred W. Haise

He was one of the brave trio that took on the odds on the Apollo 13 mission

Fred Haise was with NASA for over 15 years

Imagine watching the Moon go past your eyes knowing that you could be walking along the surface, but it wasn't to be as there were more concerning matters at hand.

The unfortunate story of Apollo 13 meant that James Lovell and Fred Haise wouldn't complete their mission that would have made them the fifth and sixth men on the Moon. On the positive side, they did return safely back to their families. This is just one highlight from the career of astronaut Fred Haise, a man who made notable contributions to the most beneficial period of space exploration.

Born on 14 November 1933 in Biloxi, Mississippi, United States, Haise took a route to astronautic stardom that many aspiring astronauts take. Haise began his career in a military and aviation fashion, first being trained as a test pilot, then going on to the Navy and working his way up through the ranks, including working in the Marines. During this time Haise accumulated 9,300 hours flying time, including 6,200 hours in jets. This made him well equipped to handle the arduous requirements of spaceflight and high-pressure situations.

In April 1966 19 astronauts were chosen by NASA to perform the upcoming Apollo missions along with Neil Armstrong, Buzz Aldrin, Alan Bean and many more. The preliminary duties in the Apollo program for Haise included being the backup Lunar Module Pilot for Apollo 8 and Apollo 11. It wasn't until 11 April 1970 rolled around that Haise finally had his moment. Along with commander Jim Lovell and Command Module pilot Jack Swigert, Haise and his crew left Earth with the intention to make another successful landing on the Moon, cementing the United States as the undeniable victors in the space race.

> "Haise began his career in a military and aviation fashion"

Two days after launch the lunar landing was aborted as an oxygen tank exploded; the primary focus shifted towards getting these astronauts back home safely. All of this was portrayed in the 1995 space docudrama film *Apollo 13*, with Bill Paxton portraying Haise. With the odds against the trio, including limited power, loss of cabin heat, a shortage of potable water and the dire need of repairs to the carbon-dioxide-removal system, the crew returned back to Earth on 17 April 1970, deeming the mission a "successful failure".

This performance earned Haise his commander stripes for Apollo 19, but that was never to happen as NASA focused its budget towards other matters, including the Space Shuttle program. Haise was very influential in the early stages of the Space Shuttle program and became technical assistant to the manager of the Space Shuttle Orbiter Program in 1973. He also participated in the approach and landing tests and piloted Space Shuttle Enterprise in three successful landings. These tests laid the foundations for the Space Shuttle program. In June 1979 Haise retired from NASA before taking on different projects. His accolades celebrate a fantastic career that benefitted a nation in a time of extraordinary feats in space exploration.

The crew of Apollo 13 following splashdown

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All About Space

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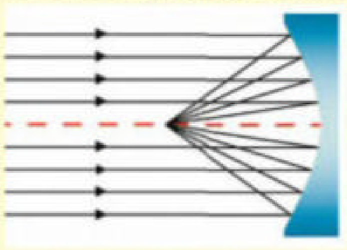

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